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The Effects of Urban Containment Policies on Commuting Patterns

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The Effects of Urban Containment Policies on Commuting Patterns

by

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Abstract

During the past several decades, most U.S. metropolitan areas have experienced strong suburbanization of housing and jobs (i.e., urban sprawl). The sprawl that arises from urban growth has become a big issue in many metropolitan areas in the U.S. In response, there has been increased interest in urban containment policies. There are contrasting views (planning-oriented vs. market-oriented) of urban sprawl and urban containment policies. Planning-oriented scholars asserted the problems of ‘geographic sprawl (GS)’ and the positive effects of urban containment polices, while market-oriented scholars asserted the problems of ‘economic sprawl (ES)’ and the negative or negligible effects of urban containment policies. Therefore, this dissertation analyzed whether urban containment policies affect urban sprawl, employment center formation, and urban commuting.

The results of this dissertation indicate that urban containment policies play an important role in affecting urban sprawl, employment center formation, and urban commuting, as well as explaining the contrasting views (planning-oriented vs. market-oriented) of urban containment policies. Implementing urban containment policies can produce positive effects such as compact development, which can promote J-H balance. However, as seen in the relationship between urban containment policies, urban sprawl and housing values, stronger urban containment policies can produce negative effects, such as traffic congestion and an increase in housing prices.

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CHAPTER I

INTRODUCTION

1. 1 Research Background

Urban centers have played an important role in attracting people and jobs because of the benefits of agglomeration economies[1], which include labor market pooling, the sharing of intermediate inputs, and knowledge sharing or technological spillovers. However, agglomeration benefits can be offset by diseconomies such as congestion, pollution, and crime. People and firms have moved from central cities to suburban areas to avoid those disadvantages. This phenomenon is called suburbanization or exurbanization, and some scholars refer to its negative consequences as sprawl. Most U.S. metropolitan areas have experienced the negative consequences of the strong decentralization of housing and jobs, which includes habitat fragmentation, loss of aesthetic benefits from open space, longer commutes, accelerated decay of downtowns, lower social interaction, water and air pollution, greater infrastructure costs, and social

---

1 Agglomeration economies are the benefits that firms obtain when locating near each other. Agglomeration economies can be divided into localization economies and urbanization economies. Localization economies decrease the cost of production for every firm in a specific industry that locates within an area. Urbanization economies decrease the cost of production for every firm that locates in a particular city, regardless of industry (Edwards, 2007. p.112).

inequity (Ewing, 1997; Burchell et al., 1998; Brueckner, 2000; Porter, 2000; Squires, 2002; Brody et al., 2006).

Some planning scholars regard sprawl as the cause of increasing jobs-housing (J-H) imbalances or the spatial mismatch between employment opportunities and residential concentrations. Alternatively, other scholars assert that such an imbalance or spatial mismatch cannot account for actual commuting patterns because actual commuting activity reflects many factors that are unrelated to the mix of jobs and housing.

In addition, there are contrasting views on urban sprawl and urban containment. The market-perspective emphasizes that decentralization is a natural phenomenon, and can reduce urban commuting because urban residents are "rational locaters" (Levinson and Kumar, 1994). Alternatively, the planning perspective sees sprawl as the root cause of various urban problems, such as auto dependency, congestion, air pollution, and social segregation.

Planning scholars promote the compact city because it can reduce congestion, air pollution, and contribute to social equity. However, market-oriented scholars point out the negative consequences of urban containment policies, such as increases in housing or land prices, and reductions in housing affordability (Richardson and Gordon, 2000; O'Toole, 2007). They also argue that urban containment policies contribute to unintended inequities, such as when wealthier households own "hobby farms" that are effectively subsidized by lower land values outside the growth boundary (O'Toole, 2003). Growth containment can also threaten open spaces within urbanizing areas, because of the lack of available land (Richardson and Gordon, 2000). In addition, urban containment policies tend to restrict the choices of residents because they discourage the larger lots that most people prefer to own (O'Toole, 2003). Thus, existing literature reveals mixed perspectives on the impact of urban containment policies on urban form, urban commuting patterns, and social integration.

This research focus on the interaction among urban containment policies, urban form, and urban commuting patterns for U.S. metropolitan areas using data from Census 2000 and 2010, and Census Transportation Planning Package (CTPP) data from 2000 and 2010.

The larger questions that motivate this research are as follows:

1. Have urban containment programs influenced urban form when other relevant factors are controlled?

2. What is the effect of urban form on employment subcenter center formation?

3. What are the effects of employment subcenters on J-H balance and urban commuting, when other relevant factors are controlled?

4. Among the levels of planning intervention for controlling urban sprawl, what is the most desirable level for minimizing commuting time?

5. Are there equity consequences of the urban form / employment centers /commuting relationship?

The research based on these questions has one general purpose and two objectives. The purpose is to better understand metropolitan development patterns and the effects of urban containment polices on commuting patterns in the U.S. metropolitan areas. The objectives include: (1) to analyze the effects of urban containment programs on urban form, spatial structure, and commuting; and (2) to determine whether there is a level of growth containment intervention that balances the positive and negative urban form, spatial structure, and commuting consequences. Therefore, this dissertation will develop and estimate an empirical model using data from the 2000 and 2010 Census to examine the five questions presented above.

1.1 Research Organization

The research consists of five chapters, as shown in Figure 1. Chapter I, the introduction, includes a background discussion, the research questions, objectives and goals.

Chapter II presents a review of the literature. This chapter focuses on the relationship between suburbanization and urban sprawl, the relationship between urban form and urban commuting, the relationship between urban containment policies and urban commuting, and urban containment policies for urban sprawl. The first section of the chapter explores stages of urban development and the difference between suburbanization and urban sprawl, and then defines urban sprawl for this study. The second section of chapter reviews the features between Monocentric City and Polycentric City and examines the effect of urban form (i.e., Monocentric City vs. Polycentric City) on urban commuting. The third section of the chapter defines urban containment policies and reviews the effect of urban containment policies on urban commuting and urban sprawl. The last section of literature review examines two alternative perspectives for interpreting metropolitan suburbanization. Finally, Chapter II identifies the limitations of existing literature.

Chapter III covers the study areas, data sources, statistical methods, geographic information system (GIS) techniques, indexes for variables, and statistical hypotheses. This research uses the 350 metropolitan statistical areas (MSAs) in the U.S. for the study areas. This chapter provides a description of statistical methods and data sources with selected variables, and GIS techniques for calculating indexes. In this research, ArcGIS 9.3/SPSS 22 and STATA 10.0 were the primary methodological tools used for spatial analyses and advanced statistical analysis.

Chapter IV provides the analysis and results of the effects of urban containment policies on urban structure and urban commuting based on the research hypotheses introduced in Chapter III.

Chapter V concludes with critical findings and policy implications for the relationship between urban containment policies and commuting in U.S. metropolitan areas with different forms and levels of planning options.

Figure 1. Research Organization

CHAPTER II

LITERATURE REVIEW

This literature review summarizes the current level of knowledge regarding the relationship between urban containment policies, urban sprawl, employment center formation, and urban commuting. The review also addresses the most appropriate tools and procedures for examining these issues, and their associated methodological challenges. Finally, the literature reviews identifies the limitations of existing research that this dissertation intends to address.

The literature review concentrates on the following clusters of research: the role of urban containment policies in limiting urban sprawl, the relationship between urban sprawl and urban spatial structure, and the role of the urban spatial structure in urban commuting. The last section of the chapter then explores and defines two perspectives for analyzing metropolitan suburbanization.

2.1 Stages of Urban Development

In general, urban development can be divided into four stages, as summarized in Table 1 (e.g., Klaassen et al., 1981; Champion, 1986; Ha and Kim, 1992). The first stage is the initial urbanization period where population in the urban core increases as people in rural areas migrate to urban areas to seek jobs. Urban economic activities are concentrated in the core area.

The second stage is the suburbanization period. In this stage, population in the urban core area continues to grow. However, the increase in population of the suburban area is greater than the urban core area. Higher income people move to suburban areas seeking amenities. In this stage, commuting time or distance increases because of a growing spatial mismatch between jobs and housing.

The third stage can be divided into de-urbanization (Klaassen et al., 1981; Champion, 1986) and employment suburbanization (Ha and Kim, 1992). De-urbanization occurs when the total urban population decreases. That is, the growth of population and jobs in the suburban area is slower than the decline of population and jobs in the core area. Commuting time or distance may increase or decrease depending on degree of mismatch between jobs and housing. However, employment suburbanization contributes to a transformation from a monocentric to a polycentric spatial structure. Firms relocate to suburban areas because of low land prices and greater accessibility to people who have moved to suburban areas. Sometimes, in this stage, jobs and housing become better matched. Therefore, travel time or travel distance can be reduced.

The last stage can be divided into both re-urbanization (Klaassen et al., 1981; Champion, 1986) and post suburbanization (Ha and Kim, 1992). Re-urbanization relates to decreases in population and jobs in suburban areas and increases in population and jobs in urban core areas. Post suburbanization focuses on the function of polycentric cities in a metropolitan area.

Table 1. Stages of Urban Development

	Stage of Development	Features
1	Urbanization	Increase of population in urban core
2	Suburbanization	Greater population growth in suburban areas than urban core areas
3	De-urbanization	Overall decline in urban population
	Employment suburbanization	Evolution from monocentric to polycentric form
4	Re-urbanization	Decrease in population and jobs in suburban areas and increase in population and jobs in urban core areas
	Post suburbanization	Focus on the function of polycentric cities

Source: author reconstruction based on Klaassen et al. (1981), Champion (1986), and Ha and Kim (1992)

2.2 Suburbanization Theory

2.2.1 The Relationship Between Suburbanization and Urban Sprawl

As discussed in the previous chapter, urbanization has four stages. Within these stages, urbanization has two main powers: *centripetal power* and *centrifugal power*. Centripetal power concentrates population and economic activities in urban core areas. Centripetal power plays an important role in first stage of urbanization. However, population and economic activities move outside to the urban core areas when diseconomies such as (traffic) congestion, air or water pollution, crime, and increases in housing price expand to offset the core's agglomeration benefits. This phenomenon can be explained by the centrifugal power, which pushes population and jobs to suburban areas. This phenomenon is called "suburbanization."

Then, what is urban sprawl? Downs (1997) defined sprawl as "a particular form of suburbanization with several characteristics that differentiate it from other conceivable forms of suburbanization (p. 382)." Downs (1999) defined sprawl as: 1) unlimited outward extension of development; 2) low-density residential and commercial settlements; 3) leapfrog development; 4) fragmentation of powers over land use among many small localities; 5) dominance of transportation by private vehicles; 6) lack of centralized planning or control of land uses; 7) widespread strip commercial development; 8) great fiscal disparities among localities; 9) segregation of types of land use in different zones; and 10) reliance mainly on the trickle-down or filtering processes to provide housing to low-income households (p. 956).

Ewing et al. (2002) identified four dimensions of sprawl: 1) a population that is widely dispersed in low density development; 2) rigidly separated homes, shops, and workplaces; 3) a network of roads marked by huge blocks and poor access; and 4) a lack of well-defined, thriving activity centers, such as downtowns and town centers (p 3). In addition, he asserted that sprawl reduces transportation choices, affordable housing, and walkability.

Beck et al. (2003) identified five features of sprawl: 1) the progressive loss of open space at urban perimeters as an urban area grows and spreads into the surrounding countryside; 2) low-density character, in contrast to compact urban cores; 3) chaotic, or unplanned development; 4) dependence on the automobile; and 5) connection with the decay of inner cities (p. 23).

Based on above definitions of sprawl, Lee and Leigh (2005) defined urban sprawl as “uncontrolled suburbanization.” Thus, urban sprawl is dispersed low-density, auto dependent development, and excessive spatial growth of cities (Brueckner, 2000; Lee and Leigh, 2005). Therefore, urban sprawl is a social phenomenon arising from uncontrolled suburbanization.

2.2.2 The Causes of Suburbanization and Urban Sprawl

Many metropolitan areas in the U.S have experienced urban sprawl. Urban sprawl is creating negative impacts including habitat fragmentation, the loss of aesthetic benefits from the presence of open space, longer commutes, the decay of downtowns, reducing social interaction by low density housing, water and air pollution, and increasing infrastructure costs, inequity, and social stagnation (Ewing, 1997; Porter, 2000; Brueckner, 2000; Squires, 2002; Brody et al., 2006). Therefore, many metropolitan areas have implemented urban growth management policies to limit urban sprawl or address the problems that arose from urban sprawl.

Urban scholars and experts have discussed reasons for suburbanization and urban sprawl (Bradbury, Downs, & Small, 1982; Mieszkowski & Mills, 1993; Brueckner, 2000). Bradbury, Downs, and Small (1982) mentioned the causes of sprawl as: 1) rising real income; 2) greater use of cars and trucks; 3) widespread desire of people for living in relatively new and low-density settlements; 4) economic advantages of home ownership (the support of government to purchase housing); and 5) strongly entrenched tendencies for people to segregate themselves socioeconomically and racially by neighborhoods (p12).

Mieszkowski and Mills (1993) assert that the causes of sprawl include home mortgage insurance by the federal government, development of the interstate highway system, racial tensions, crime, and schooling considerations.

Brueckner (2000) identifies three factors, which are growing population, rising incomes, and falling commuting costs. Brueckner (2000) also emphasizes three kinds of market failure: 1) failure to account for the social value of open space, 2) failure to account for the external cost of freeway congestion, and 3) failure to fully account for the infrastructure cost of new development.

Mieszkowski and Mills (1993) and Lee and Leigh (2005) mention two theories that support suburbanization: *natural evolution theory* and *flight from blight.* Natural evolution theory focuses on declining transportation cost and rising income. When a city forms, the urban core is firstly developed as the hub of transportation. Given high transportation costs, employment and residential areas are concentrated near the urban core. However, when land in the urban core becomes filled in, development moves to land farther out. As new housing is built in suburban areas, higher income groups move there because they prefer new and larger housing compared to higher commuting costs. This phenomenon segregates the housing market. That is, households with low income remain in the central city, and households with high income now live in suburban areas.

Alternatively, the flight from blight theory emphasizes fiscal and social problems as they relate to Tiebout's (1956) theory.[2] Middle and high-income groups move to suburban areas to avoid the core's high taxes, low quality public schools and other government services, racial tension, crime, congestion, and low environmental quality.

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2 Tiebout's (1956, p. 418) hypothesis states, "The greater the number of communities and the greater the variance among them, the closer the consumer will come to fully recognizing his/her preference position." Therefore, people with rational behavior choose public goods or services as described by "voting by foot," which means consumer-voters move to that community whose local government best satisfies their set of preferences.

From both theories, we may therefore summarize that the main causes of suburbanization and urban sprawl are the rise in incomes, government support for housing, improvement of the transportation system, market failure, and the pursuit of amenities.

2.3 The Monocentric vs. Polycentric Model

In the classical urban land use model, the relationship between urban spatial patterns and travel has been extensively explored. Both residential and firm location decisions are considered to be sensitive to commuting and access costs. The monocentric and polycentric models explain the location choice process of households and firms.

The monocentric model of urban land use was developed by Alonso (1964) and Mills (1972). The model includes the utility functions of households and the cost/profit functions of firms, which consist of production, housing (or land), and transportation costs. In this model, a metropolitan area has a central business district (CBD) where all workers are employed. Commuting costs and land (or housing) prices play the most important role in worker's residential location decisions (Alonso, 1964; Mills, 1972). The residential bid price curve is "the set of prices for land the individual could pay at various distances while deriving a constant level of satisfaction (Alonso, 1964, p. 59)." That is, residents choose their housing location by trading off commuting and housing costs to maximize utility. Residents will locate where their marginal commuting costs are equivalent to the marginal savings on housing. In other words, given the location and the availability of houses and jobs, residents choose a utility-maximizing location to minimize aggregate commuting distances, other things being equal (Mills, 1972). Workers can choose residential locations at increasing distances from the CBD, although their commuting costs also increase with distance. The bid-rent function for land also explains non-residential land uses, such as commercial and industrial activity.

As mentioned above, the monocentric model emphasizes the trade-off between transportation costs (or commuting costs) and land (or housing) prices. In reality, this relationship has become less important in the location choices of households and firms because other factors, such as improved technology, rapid job turnover, high moving costs, two-worker households, the increasing importance of non-work trips, and the increasing importance of amenities have become more important (Giuliano and Small, 1993).

Changing urban commercial development patterns have also resulted in the emergence of urban subcenters. The monocentric model has been replaced by a polycentric extension with multiple urban centers (or suburban centers and "edge cities"). According to Anas, Arnott and Small (1998), research based on the polycentric model leads to the following generalizations: 1) subcenters are evident in both new and old cities; 2) the number of subcenters and their boundaries are quite sensitive to definition (i.e., employment density and total employment thresholds); 3) subcenters are often arrayed along transportation corridors; 4) the location of subcenters often helps explain the surrounding distribution of employment and population; 5) subcenters have diminished but have not eliminated the predominance of the CBD; 6) a majority of metropolitan employment still resides outside the CBD and subcenters; 7) neither commuting time nor distance is well explained by monocentric or polycentric models;

and 8) the decentralization of subcenters has tended to follow and reinforce the decentralization of population.

2.4 The Relationship between Urban Form and Commuting

Commuting patterns in the polycentric model are different from the monocentric model. In the monocentric model, decentralization of population increases commuting distance and time (Cervero and Wu 1998). In the polycentric model, decentralization of employment reduces commuting time (Gordon et al., 1991). This difference can be explained by the 'co-location hypothesis' (Gordon et al., 1989; Gordon et al., 1991). In the polycentric model, decentralized jobs create subcenters without renouncing the advantages of agglomeration, and it also tracks decentralized housing and population. Therefore, a polycentric city can reduce the costs of commuting and traffic congestion. In other words, a polycentric city can be interpreted as a more desirable urban structure when a city is growing.

Since the early 1980s, studies have addressed “wasteful commuting” in regard to the ability of the monocentric and polycentric models to explain residential location behavior. There is a general consensus that actual commute time is much longer than the theoretical minimum commute time (Hamilton, 1982; White, 1988; Small and Song, 1992; Giuliano and Small, 1993; O'Kelly and Lee, 2005; Ma and Banister, 2006). Wasteful commuting is usually interpreted as non-optimized commuting travel within a given city form (Scott et al., 1997; O'Kelly and Lee, 2005; Ma and Banister, 2006). Operationally, wasteful commuting is defined as the difference between the observed average commute and the theoretical minimum average commute resulting from assigning worker-residents to the CBD (in the monocentric application) or the nearest employment center (in the polycentric application). This difference is typically expressed as a percentage of the actual commute. Thus, wasteful commuting (*W*) can be formulated as follows:

$$W = \left(\frac{Ta - Tr}{Ta}\right) \times 100$$

Where, *W* = wasteful commuting; *Ta* = the actual observed average commute; *Tr*= the theoretical minimum average commute.

Research on wasteful commuting began with Hamilton's (1982) study. Hamilton sought to determine whether workers minimized their average commuting distance consistent with the monocentric model. He found that there is considerable wasteful commuting (averaging approximately 87% of total observed commuting) in the case of 14 American and 27 Japanese cities. The results thus showed that the monocentric model significantly underestimates actual commuting distance. Hamilton's (1982) work, however, triggered a series of follow-up studies, since he did not fully operationalize the actual distribution of housing and jobs, or actual road networks.

Following Hamilton (1982), White (1988) estimated wasteful commuting time in 25 US metropolitan areas by operationalizing the actual distribution of housing and jobs and the actual road network. White (1988) found a considerably smaller proportion of wasteful commuting compared to Hamilton, and she concluded that the monocentric model framework itself is not problematic. Methodologically, White's approach offers a useful tool for examining travel behavior without the strict assumption of the standard monocentric model because her method considered the on-going changes in the distribution of population and employment. Most subsequent studies have followed White's approach to estimating wasteful commuting.

Small and Song (1992) considered both time and distance in estimating wasteful commuting. Their results showed that there were only minor differences between the outcomes for distance and time. With respect to the modeling techniques, however, they concluded that Hamilton's (1982) and White's (1988) approaches are dissimilar because White's (1988) analysis focused on cost minimization with the empirical testing of commuting among actual zones, whereas Hamilton (1982) focused on cost minimization compared to the monocentric optimization of commuting among hypothetical zones.

Giuliano and Small (1993) used White's (1988) method to examine whether urban spatial structure (or J-H balance) explains commuting costs, and whether urban policies related to housing supply and employment provision affect commuting patterns. Their results indicated that there is considerable wasteful commuting in the Los Angeles metropolitan area. In addition, they asserted that urban land use policies to reduce commuting would be limited by such factors as multiple wage-earners, non-work travel, public service preferences, and amenities that divert residential choices from commute-minimizing locations.

Merriman et al (1995) examined wasteful commuting in Tokyo. The percentage of wasteful commuting they found was smaller (commuters in LA waste twice as much time in a commute that is half as long as commuters in Tokyo) than that of Small and

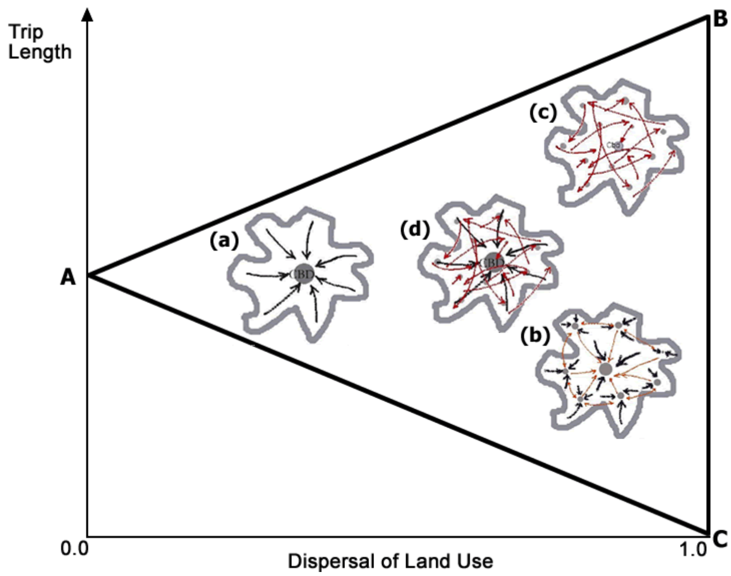
Song (1992) because of differences in analysis zone size and the analysis method of commuting time employed. They demonstrated through their nine simulations (decentralization of employment and/or centralization of residents) that a polycentric representation of Tokyo reduces wasteful commuting.

O'Kelly and Lee (2005) studied the relationship between excess commuting and J-H balance by examining disaggregated journey-to-work data by occupation in Boise, Idaho, and Wichita, Kansas. Their results showed that the relationship between excess commuting and J-H balance is not uniform across occupations. Based on these findings, they asserted that excess commuting is a measure of potential commute reduction because it is greater in zones where jobs are lacking.

Ma and Banister (2006) used an extended excess commuting technique, which identifies the feasible commuting range that any city form can have to analyze both quantitative and qualitative imbalances in the Seoul metropolitan area. Through empirical testing of the extent to which workers' location optimization was reflected in the actual commuting trips with respect to the J-H balance, their extended excess commuting measure is shown to be a useful tool for identifying the feasible commuting range and differentiating between quantitative imbalance and qualitative imbalance. They also found that wasteful commuting is significantly related to J-H imbalance.

Banister (2012) studied the relationship between urban structures (i.e., Radial Cities, City Clusters, and Axial Cities) and commuting in Chinese cities. The results are illustrated in Figure 2. The Figure shows that different urban forms can have different trip lengths. That is, urban decentralization could either lengthen or shorten the commute.

The reason for this result is different according to the city's economic, political, or geographical situations, transportation systems and a number of socio demographic factors such as income, race, sex, education level, housing price, and worker's preference.



Source: Bertaud (2002); Banister (2012)

Notes: City (a) is the monocentric model; City (b), the polycentric model (the urban village version); City (c), the polycentric model (the random movements version), and City (d), the mono-polycentric model (simultaneous radial and random movement) (Bertaud 2002; Banister 2012).

Figure 2. The Relationship Between Trip Length, Patterns, and Urban Form Within a Metropolitan Area.

Table 2. Studies of the Relationship between Urban Form and Commuting

Study	Method	Study Area(s)	Key Results
Hamilton (1982)	Monocentric model (exponentially declining density functions)	14 U.S. and 27 Japanese cities	There is considerable wasteful commuting. The monocentric model significantly underestimates actual commuting distance.
White (1988)	Linear programming calculations using travel flow data	25 U.S. MSAs	There is a considerably smaller proportion of wasteful commuting, compared to Hamilton. The monocentric model framework itself is not problematic.
Small and Song (1992)	Exponentially declining density functions and linear programming calculations	Los Angeles-Long Beach Metro area	There are only minor differences between the outcomes for distance and time.
Giuliano and Small (1993)	Linear programming calculations using the Urban Transportation Planning Package (UTPP)	Los Angeles County	There is considerable wasteful commuting. Urban land use policies to reduce commuting would have a limited effect.

Table 2. Studies of the Relationship between Urban Form and Commuting (Continued)

Study	Method	Study Area(s)	Key Results
Merriman et al. (1995)	Nine simulations based on White's method	Tokyo	A polycentric spatial structure reduces wasteful commuting
O'Kelly and Lee (2005)	A disaggregated version of a linear programming model	Boise, Idaho, and Wichita, Kansas	The relationship between excess commuting and J-H balance is not uniform across occupations.
Ma and Banister (2006)	An extended excess commuting technique	Seoul MSA	Wasteful commuting is significantly related to J-H imbalance.
Banister (2012)	Comparative Analysis	28 Chinese cities	Different urban forms can have different trip lengths.

2.5 Urban Containment Policies

The sprawl that arises from urban growth has become a big issue in many metropolitan areas in the U.S. In response, there has been increased interest in urban containment policies.

Urban containment policies include the formal designation of an urban growth boundary (UGB), infrastructure policies, and other policies related to urban growth that serve to control or manage its impact (Kelly 1993). Nelson and Duncan (1995) observe that urban containment policies include government regulation as well as public ownership of land, and policies regarding the timing and sequencing of public infrastructure construction. Based on Nelson and Duncan (1995), Pendall et al. (2002) classified urban containment policies of two kinds: “1) urban growth boundaries and related strategies, and 2) infrastructure policies (p 3).” Pendall et al. (2002) also defined urban containment as ‘creating geographical constraints on urban growth.’ In general, the purpose of urban containment policies is to constrain urban sprawl and achieve a more compact utilization of land in metropolitan areas (Pendall et al., 2002). According to Nelson et al. (2007), there are five goals of urban containment policies: 1) preserve public goods such as clean air, water and significant landscapes; 2) minimize negative externalities; 3) minimize public fiscal costs; 4) maximize social equity; and 5) improve quality of life. According to Pendall et al. (2002), urban containment policies can be divided into “push” and “pull” orientations. They explain as follows:

By placing land out of bounds, open space constraints "push" urban growth away from them and therefore in a different direction. By locating in specific areas and along specific routes, public infrastructure "pulls" urban growth toward those areas and therefore away from other locations where it does not already exist (p.4).

Urban containment policies with a "push" orientation include greenbelts and urban growth boundaries (UGB). Urban containment policies with a "pull" orientation include urban service areas. Thus, the purpose of urban containment policies, either "push" or "pull" oriented, is to accomplish a more orderly and intensive utilization of land in metropolitan areas.

The UGB is a legal boundary separating urban from rural land. The boundary is set in an attempt to control urbanization by designating the area inside the boundary for higher density urban development and the area outside the boundary for lower density rural activity (Pendall et al., 2002). Greenbelts are a limiting example of a UGB. Pendall et al. (2002) defined the greenbelts as "a band drawn fairly tightly around a city or urban region that planners intend to be permanent or at least very difficult to change." In contrast, an urban service boundary (USB) is more flexible than a UGB because governments can control the construction of public services such as sewer and water.

2.6 Urban Sprawl vs. Urban Containment

Urban sprawl and growth containment have been contentious subjects in urban planning. In general, some scholars have asserted the need for urban containment policy (smart growth or compact city) (Barnett, 2007; Beatley, 2000), due to the problems caused by urban sprawl. However, others have asserted the problems of containment policy, such as increases in housing or land prices, reduced housing affordability (Richardson and Gordon, 2000; O'Toole, 2007), and decreases in both the quantity (i.e. size) and quality of new housing stock (Hall 1997).

There have been many discussions about the effects of urban containment policies on urban spatial structure (Nelson and Duncan, 1995; Hall, 1997; Pendall et al., 2002; Dawkins and Nelson, 2002; Anthony, 2004; Jun, 2004; Nelson et al., 2004a; Nelson et al., 2004b; Brody et al., 2006; Rodriguez et al., 2006; Wassmer, 2006; Carlson and Dierwechter, 2007; Park and Kwon, 2009; Woo and Guldmann, 2011; Geshkov and DeSalvo, 2012). Hall (1997) reviewed the British green belt program experience. He concluded that containment of urban development was the most positive outcome of the program. Hall also concluded that the program had several negative effects. First, by limiting the supply of land, the program increased the cost of housing construction. In response, both the average size and quality of new housing stock declined. Second, the British green belt program included development of satellite settlements. Although urban and satellite settlement densities increased, overall employment accessibility actually declined. Thus, the goals of reducing work travel distances and promoting transit use were not achieved.

Other scholars have observed the positive effects of regulatory approaches to minimizing the amount of land converted from rural to urban uses and promoting compact development (Wassmer, 2006; Pendall *et al*., 2002). In addition, urban containment policies have been found to promote the revitalization of central cities (Nelson et al., 2004b) and new housing development within the boundary (Carlson and Dierwechter, 2007).

Dawkins and Nelson (2003) found that state growth management programs affected the spatial distribution of residential construction activity within urban areas, based on their analysis of new residential building permits in 293 metropolitan statistical areas with or without states growth management programs. More specifically, they concluded that state growth management programs serve as an effective tool for promoting the revitalization of central cities.

Nelson et al. (2004a) tested whether areas with urban containment policies reduce residential segregation between white and black residents in 242 metropolitan statistical areas. Their results showed that urban containment reduces residential segregation.

Nelson et al. (2004b) examined the effects of urban containment policy on development activities in central cities by estimating seven regression equations covering the total number of units constructed for single-family and multifamily residences, and residential additions; the total value of construction per capita for commercial additions, retail/wholesale, and office; and industrial development in central cities in 144 central cities in 1990. Their results showed that urban containment policies encouraged construction activities in central cities.

Wassmer (2006) found that growth management policies lead to compact urban development by analyzing densities in the 452 Census-designated urbanized areas in the U.S. with or without local and state growth management programs or urban containment policies.

Carlson and Dierwechter (2007) used a kernel density calculation on geocoded residential building permit data from1991 to 2002 to see whether urban growth boundaries affect residential construction activities. Their results showed that urban growth boundaries substantially increased residential permits inside those boundaries in Pierce County, Washington.

Woo and Guldmann (2011) used a simultaneous equation model to examine the impacts of different types of urban containment policies on the spatial structure of 135 US metropolitan areas. They found that state-mandated ‘strong’ urban growth boundaries promoted more development activities and greater population density within the boundaries than locally adopted urban growth boundaries or urban service areas.

Geshkov and DeSalvo (2012) studied the effect of land-use controls on the spatial size of 182 U.S. urbanized areas in 2000. Their empirical results showed that most land use control variables had effects that were consistent with theoretical prediction, although urban growth boundaries were not statistically significant.

Dawkins and Nelson (2002) addressed the relationship between urban containment policies and housing prices. They concluded that containment policies raise land prices and decrease housing affordability, based on a review of existing studies on the housing price effects of growth controls and other similar land use policies.

Anthony (2004) found that states with growth management generally experienced a lesser density decline than states without growth management. However, his regression results showed that state growth management programs did not have a statistically significant effect in checking sprawl.

Jun (2004) analyzed the effects of the UGB on new housing construction in the Portland metropolitan area between 1980 and 2000. The results showed that UGB did not affect the rate of suburban housing construction over time, although residential development was diverted to Clark County Washington.

Most studies of urban containment polices are related to housing price or density. There is less research on the relationship between urban containment policies and urban commuting (Rodriguez et al., 2006; Jun, 2004; Brody et al. 2006; Park & Kwon, 2009). Jun (2004) also found that the Portland region's suburbanization of development resulted in an increase in commuting time.

Rodriguez et al. (2006) analyzed the relationship among urban containment policies (UCPs), density, and transportation outcomes (vehicle miles traveled: VMT) in the largest 25 U.S. metropolitan areas. They concluded that UCPs tend to increase population density over time at a decreasing rate, but also increase VMT and worsen congestion in some metropolitan areas. They concluded that the cause of increased

VMT is higher housing prices within containment areas. These results support the hypothesis that UCPs positively impact public transit use and supply by increasing density and by raising the costs of automobile travel.

Brody et al. (2006) analyzed the effects of socioeconomic, demographic, and environmental variables on the implementation of a sprawl reduction measure in Florida. The socioeconomic factors (population density, median home value, education, and planning capacity) had a statistically significant effect on the adoption of sprawl-reducing planning policies. However, the environmental variables (biodiversity and human disturbance variables) were not significant.

Park and Kwon (2009) found evidence, utilizing the econometric analysis, of the relationship of census tract level J-H ratios and commuting time in the Portland MSA, with the St. Paul-Minneapolis MSA as another case city and the Cleveland MSA as the control region. Although the results on the Portland case (and other U.S. cases) have not been fully verified in the literature, the relationship of residential and employment opportunities and balance and commuting becomes increasingly important regarding land use and urban growth management.

Table 3. Studies of the Relationship Between Urban Sprawl and Urban Containment Policies

Study	Study Area(s)	Key Results
Hall (1997)	The British green belt program experience	Green belts contained urban development, but also increased housing prices, reduced housing quality, and reduced access to employment.
Dawkins and Nelson (2003)	293 U.S. MSAs	State growth management programs affected the spatial distribution of residential construction activity within urban areas
Nelson et al. (2004)	242 U.S. MSAs	Urban containment reduces residential segregation.
Nelson et al. (2004b)	144 U.S. central cities	Urban containment policies encouraged construction activities in central cities.
Wassmer (2006)	452 U.S. urbanized areas	Growth management policies lead to compact urban development.
Carlson and Dierwechter (2007)	Pierce County, Washington	Urban growth boundaries increased residential permits inside those boundaries.
Woo and Guldmann (2011)	135 U.S. MSAs	State-mandated ‘strong’ urban growth boundaries promoted more development activity and greater population density within the boundaries.
Geshkov and DeSalvo (2012)	182 U.S. urbanized areas	Most land use control variables had effects that were consistent with theory.

Table 3. Studies of the Relationship Between Urban Sprawl and Urban Containment Policies (Continued)

Study	Study Area(s)	Key Results
Dawkins and Nelson (2002)	UK, Korea, Oregon, California, Colorado, Minnesota	Containment policies raise land prices and decrease housing affordability
Anthony (2004)	49 U.S. states	Urban areas have expanded considerably and urban densities have declined.
Jun (2004)	Portland MSA	The UGB did not affect the rate of suburban housing construction over time and increased average commuting time.
Rodriguez et al. (2006)	25 U.S. MSAs	UCPs tend to increase population density over time at a decreasing rate, but also increase VMT and worsen congestion in some metropolitan areas.
Brody et al. (2006)	Southern Florida	Socioeconomic factors influenced the adoption of sprawl-reducing planning policies.
Park and Kwon (2009)	Portland, Minneapolis, and Cleveland MSAs	Growth management policies help to offset the more slowly increasing opportunity cost of commuting time by faster-increasing employment opportunities.

2.7 Two Perspectives for Analyzing Metropolitan Suburbanization

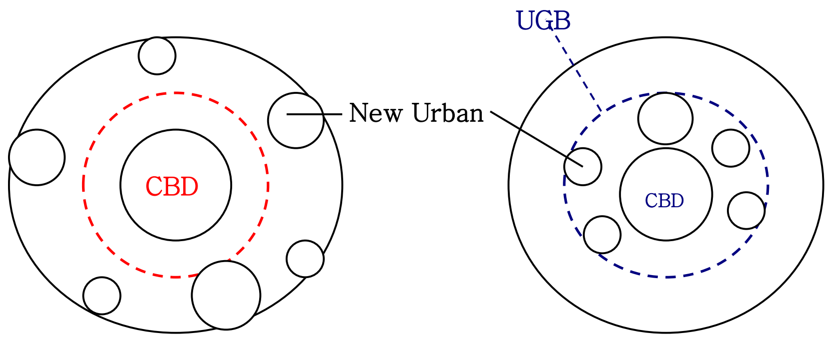
Regarding the diagnoses and remedies of the problems of suburbanization, two major approaches can be defined: 1) planning approaches emphasize that planned interventions or planning (efforts) usually advocate growth control (Newman and Kentworthy, 1989, 1992; Cervero, 1991; Bourne, 1992; Nass and Sandberg, 1996; Cervero and Wu, 1998; Rodriguez, et al., 2006; Park and Kwon, 2009); 2) market approaches argue that little or no regulation of urban growth is appropriate (under assumptions of a self-adjusting market) (Gordon et al., 1991; Wachs et al., 1993; Levinson and Kumar, 1994; Gordon and Richardson, 1997; Levine, 1998; Glaeser and Kahn, 2003).

The contrasting views between the market and planning approaches can also be drawn from the definition of urban sprawl. For example, urban sprawl is defined by Anas and Pines (2008) as an expansion of urban land area and a discontinuous pattern of land development. Thus, they distinguish between two types of sprawl. Overall urban area expansion such as leapfrog development is termed '*geographic sprawl* (GS)', while increases in the economic cost of human interaction in an urban area is referred to as '*economic sprawl* (ES)'. In their view, planning scholars stress geographical sprawl (GS) whereas the scholars with market approach emphasize economic sprawl (ES).

Figure 3distinguishes the contrasting views on urban commuting. The scholars with a market approach (A) stress that J-H imbalances will be adjusted towards the equilibrium of traded-off of job accessibility and transportation costs (Wachs et al., 1993;

Levinson and Kumar, 1994; Gordon and Richardson, 1997; Levine, 1998). Additionally, commuting will be reduced by job and residential location changes. This approach assumes that the rational locator's short-term benefits from such adjustments will also lead to long-term social benefits and efficient land use (Gordon et al., 1991; Wachs et al., 1993; Levinson and Kumar, 1994; Gordon and Richardson, 1997; Levine, 1998). Alternatively, planning approach scholars (B) emphasize the long-term imperative of "making land use more efficient" or "controlling inefficient land use" (Newman and Kentworthy, 1989, 1992; Cervero, 1991; Bourne, 1992; Nass and Sandberg, 1996; Cervero and Wu, 1998; Park and Kwon, 2009). The scholars emphasizing urban growth control argue that the J-H imbalance will not be adjusted to a desirable level (Newman and Kentworthy, 1989, 1992; Bourne, 1992; Cervero and Wu, 1998; Park and Kwon, 2009).

In addition to exogenous factors pushing out existing population to the suburbs (e.g. 'surplus' labor migration into urban areas (due to the advance in agricultural technology and its consequential productivity increase)), planning interventions and policies addressing suburbanization are assumed to make different patterns of urban sprawl in U.S. metropolitan regions. It is apparent that commuting time is more likely to grow in the hypothetical suburbanization case (A), because of citizens' rational "exit" option (Hirschman, 1970) of being pushed out as a response to the decline of inner cities. As suburbanization (A) expands, accumulated rational location behavior could thus result in *increased* commuting time and *fragmented* employment opportunities under the policy principle of *laissez-faire*.



(A) Suburbanization without a UGB (B) Suburbanization with a UGB

Figure 3. Hypothetical Suburbanization With and Without an Urban Growth Boundary

There is still a debate in the literature over the effectiveness of various government interventions in actually reducing commuting. However, such effectiveness depends on either positive (nomothetic) or idiographic aspects of those policies and particularly on an imbalanced or non-optimized level of jobs and housing allocation in the given or planned urban spatial structure. Thus, although there are contrasting views of the effectiveness of urban policies to improve commuting efficiency, there is (at least) a general consensus on the existence of a 'balanced' level of jobs and houses in terms of commuting, holding other factors constant (Park and Kwon, 2009). The efficacy of urban containment efforts to improve commuting efficiency, in addition, has received considerable attention since the early 1990s (Pendall et al., 2002; Nelson et al., 2007). Thus, while acknowledging that there has not yet been a generalizable (one-size-fits-all) theoretical or empirical framework to represent the diversity of urban 'quantitative' and 'qualitative' differences (Ma and Banister, 2006), this section concludes with an outline of an ‘empirical approach’ to examine the effects of urban containment policies on commuting.

Urban containment policies are tools to facilitate the orderly development of a region. Nelson et al. (2007) emphasized the social benefits of urban containment policies, though their work did not directly relate to commuting. Rather, they focused on issues such as the relationships among urban sprawl, housing prices, affordable housing supply, and racial segregation, which influence commuting. In particular, they asserted that urban containment policies can promote J-H balance within small areas by encouraging infill development and redevelopment. Urban containment policies can also improve accessibility to work, shopping, and services.

Based on Pendall et al. (2002) and Nelson et al. (2007), the logic of the analytical framework relating to urban containment and commuting can be summarized as follows. In terms of the utilization of land in metropolitan areas and the reduction of commuting, J-H balance would play an important role. Urban containment policy can improve J-H balance because it can constrain the decentralization of residential areas and encourage infill development and redevelopment inside the urban area. Therefore, actual commuting distance in a more balanced and densely developed area should be reduced.

2.8 Limitations of Existing Literature

Studies related to the impacts of urban containment policies have primarily focused on urban size (Wassmer, 2006; Geshkov and DeSalvo, 2012) and the spatial structure of metropolitan areas (Woo and Guldmann, 2011), on residential segregation (Nelson et al., 2004), and on central city construction activity (Nelson et al., 2004b). Studies have also focused on the relationship between urban containment, density and housing prices (Dawkins and Nelson, 2002; Anthony, 2004; Jun, 2004; Wassmer, 2006). Although research (Jun, 2004; Rodriguez et al., 2006; Park and Kwon, 2009) has addressed the relationship between urban containment policies and urban commuting, the policies were either not well represented or limited to specific settings. In addition, little work has examined the interrelationship of urban containment policies, urban form, and commuting patterns of different income groups in U.S. metropolitan areas.

In contrast, this study pursues a more comprehensive analysis of urban containment policy by examining interrelationships among containment policies, urban form, and commuting patterns. Its scope is also comprehensive, covering 350 MSAs in the U.S. over two Decennial Census periods. Finally, this study seeks to determine whether an "optimal" level of containment intervention exists wherein the effects of sprawl are minimized. This latter objective relates to Brueckner's (2000) observation that regulatory measures intended to contain sprawl are relatively easier to implement, compared to the pricing of development externalities, but more difficult to amend in response to changing development circumstances over time. He thus implies that there is a potential for such measures to become too restrictive and lead to unintended outcomes such as leapfrog development and an increase in housing prices.

CHAPTER III

METHODOLOGY

This chapter is organized into three sections. The first section describes the study areas and data that are used in the empirical analysis. The second section describes the methodology and defines the variables used. The final section presents the research hypotheses for analyzing the relationship between urban containment policies, urban sprawl, employment center formation, and urban commuting.

3.1 Study Areas and Data

This research focuses on 350 U.S. metropolitan statistical areas (MSAs) as defined in the 2000 Census[3]. In addition, this research uses Census Transportation Planning Package (CTPP) data[4] for transportation, employment, and J-H ratios, and

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3 There are 353 MSAs in 2000. This research excludes three MSAs in Alaska and Hawaii (Anchorage, AK, Fairbanks, AK, and Honolulu, HI) because of the geographical location of these two states.
Source: United States Census Bureau.
https://www.census.gov/population/www/cen2000/briefs/phc-t29/index.html
4 Sources: 2000 United States Department of Transportation.
http://www.transtats.bts.gov/Tables.asp?DB_ID=630
2010 United States Department of Transportation.

Census data for socioeconomic characteristics from 2000 to 2010 to analyze the relationship between urban spatial structure and commuting in the 350 MSAs with differential types and levels of planning intervention.

3.2 Research Methods

3.2.1 Statistical Methods

The intent of this study is to estimate the relationship between urban containment policies, urban sprawl, employment center formation, and urban commuting. Therefore, this study uses a recursive system. A recursive system approach is useful when the relationships among variables are not straightforward (Hawkins, D. M., 1997).

Figure 4 illustrates the conceptual hierarchy behind the recursive system. The dependent variables in the recursive system represent urban sprawl, employment center formation, and urban commuting. The system is structured to reflect a maintained hierarchy in which urban containment policies affect the extent of urban sprawl, which, in turn, affects employment center formation, which, in turn, affects urban commuting. In addition, if the errors of each equation in the recursive system are uncorrelated, the structural equations can be estimated by OLS regression (Fox, J., 2002).

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http://ctpp.transportation.org/Pages/5-Year-Data.aspx

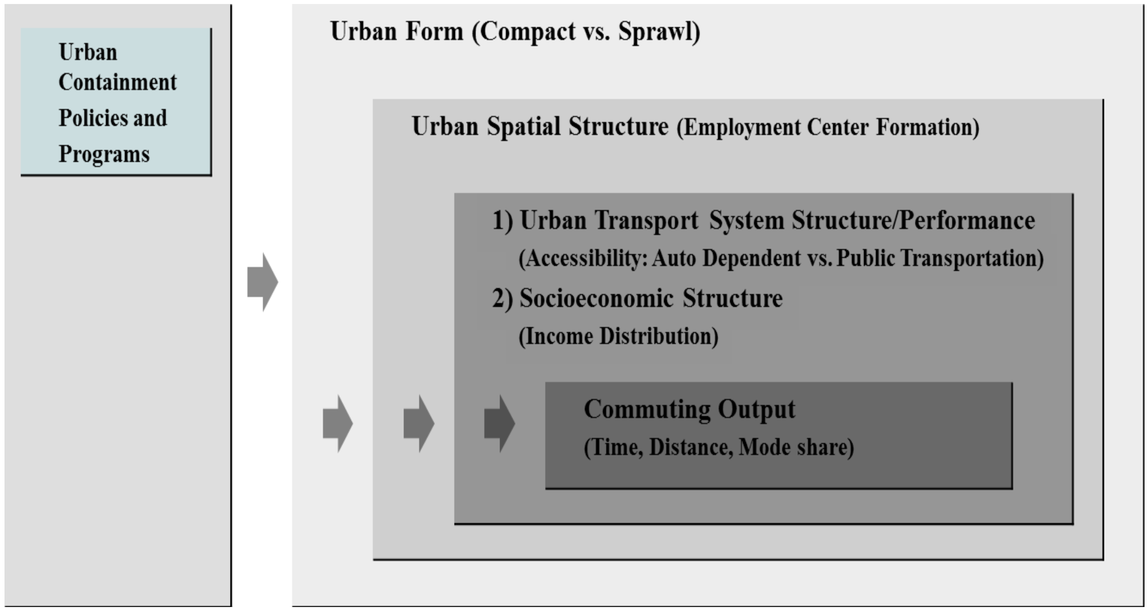

Figure 4. Modeling Framework for Analyzing the Effects of Urban Containment Policies

The recursive system to be estimated for this study consists of a set of hierarchical equations incorporating an urban containment policy index, a sprawl index, a count of employment centers, commuting time, and error terms. The equation system is specified as follows:

$$Y_1 = \beta_{10} + \gamma_{11}X_1 + \gamma_{12}C + \gamma_{13}T + u_1$$

$$Y_2 = \beta_{20} + \beta_{21}\hat{Y}_1 + \gamma_{22}C + \gamma_{23}T + u_2$$

$$Y_3 = \beta_{30} + \beta_{31}\hat{Y}_1 + \beta_{32}\hat{Y}_2 + \gamma_{32}C + \gamma_{33}T + u_3$$

Where,

Y_1 = Sprawl Index in MSAs;

X_1 = Urban Containment Index in MSAs;

$\hat{Y}_1$ = Predicted Sprawl Index in MSAs;

Y_2 = Number of Employment Centers in MSAs;

$\hat{Y}_2$ = Predicted Number of Employment Centers in MSAs;

Y_3 = Commuting Time in MSAs;

T = Time Dummy;

C = Control Variables in MSAs;

u_i = Error Term.

In addition, to test the hypotheses using the cross-sectional/longitudinal data structure of the metropolitan areas in two time periods (2000 and 2010), this study utilizes a panel data model: pooled OLS with dummy variables (fixed effects regression).

Panel data analysis requires preliminary tests such as the Breusch and Pagan (1978) test for heteroscedasticity and/or the Hausman (1978) test for endogeneity. First, if the Breusch-Pagan Lagrange multiplier (LM) test indicates no heterosedastic disturbances in a formulated regression, the analysis then can proceed to consider a pooled regression model. Second, if error heterogeneity is found, then unobserved variables' correlations with observed variables needs to be checked. In this case, the Hausman test is a specification test for the null hypothesis of exogeneity (consistent and efficient estimators) against the alternative hypothesis of inconsistent estimators. If this test does not reject the null hypothesis, the analysis may proceed to consider the random effects approach, which treats the unobserved variable as a random variable. If the null is rejected, it may proceed to the fixed effects approach, which treats the unobserved variable as an individual-specific constant.

Table 4. Fixed Effect and Random Effect Models

	Fixed Effect Model	Random Effect Model
Functional form*	$y_{it} = (\alpha + u_i) + X_{it}^{'}\beta + v_{it}$	$y_{it} = \alpha + X_{it}^{'}\beta + (u_i + v_{it})$
Intercepts	Varying across groups and/or times	Constant
Error variances	Constant	Varying across groups and/or times
Slopes	Constant	Constant
Estimation	LSDV, within effect method	GLS, FGLS
Hypothesis test	Incremental F test	Breusch-Pagan LM test

* $v_{it} \sim IID(0, \sigma_v^2)$

Source: Hun Myoung Park, 2009

Given that homoscedasticity in the residual plot is supported by the Breusch-Pagan LM test, the application of pooled ordinary least squares (OLS) regression can be employed. Inference based on OLS assumptions will be valid provided conditions of normality, no heteroscedasticity, no serial correlation, and no strong multicollinearity are satisfied for all or each point(s) of time (Beck and Katz, 1995). OLS estimation is particularly useful when the number of periods or observations are limited, compared to other methods (e.g., instrumental variable [IV] or least squares dummy variable [LSDV] estimation) (Buddelmeyer et al., 2008). The pooled model is focused on explaining the averaged pattern of aggregate changes over time. This model, however, has a limitation in distinguishing the time-specific variability or transition of individual observations. Such ‘time-specific’ variability of variables between periods can be accounted for by first-differenced estimates, given that the formulated model appropriately controls for any exceptions of strict exogeneity or incorporates them under the satisfied condition of homoscedasticity. Since the model operationally differences away the effects of unobserved heterogeneity (if it exists), it belongs to the fixed effects approach. This method also applies to the case with no unobserved heterogeneity and can therefore be used for capturing the time-specific variability of variables.

The first-differenced model, which applies to two-period (or multiple-period) data, can be formulated through the following derivation of a single cross-sectional equation (Wooldridge, 2002: 247-250):

$y_{i2} = (\beta_0 + \lambda_0) + \beta_1 x_{i2} + \eta_i + \mu_{i2}$(t = 2) ----------------------- (1)

$y_{i1} = \beta_0 + \beta_1 x_{i1} + \eta_i + \mu_{i1}$(t = 1) ----------------------- (2)

If the second equation is subtracted from the first, we obtain:

$y_{i2} - y_{i1} = \lambda_0 + \beta_1(x_{i2} - x_{i1}) + (\mu_{i2} - \mu_{i1})$, ----------------------- (3)

where the represented terms are y (dependent), λ_0 (change in the intercept), x (independent), i (cross-sectional observation) and η_i (unobserved time-constant variable), μ (residual).

The single cross-sectional equation above differences away the unobserved effect for the two periods while its intercept is the change in the intercept between t = 1 and t =

2. Given that assumptions of normality, no heterogeneity, no serial correlation, and no strong multicollinearity are satisfied, the first-differenced model then can support a valid estimation by OLS. The use of two-period panel data also helps free the model from negative moving average autocorrelation. Therefore, the first-differenced regression has an advantage when it uses two-period panel data, although longer panel changes cannot be captured. However, if a dependent variable is a time-invariant variable, the first-differenced estimation cannot be applied because the estimation is subject to bias.

Based on these theoretical backgrounds, this research involved performing basic tests for finding the most suitable panel model. First, the Breusch-Pagan Lagrange multiplier (LM) chi-square value was small, indicating heteroskedasticity was not a problem. Therefore, the application of pooled ordinary least squares (OLS) regression can be considered. In addition, to avoid heteroskedasticity this research uses the robust OLS estimator in STATA. Robust OLS estimation can deal with heteroskedasticity of the error term that creates biased standard errors of the regression coefficients, producing unreliable t-test values and confidence intervals (Wooldridge, 2002).

Second, a Chow test was applied to evaluate whether the coefficients in the linear regressions of the two time period data sets are equal (Wooldridge, 2002). The Chow test indicated that there was no significant difference. Therefore, the pooled model is chosen over the separate period models.

Third, the Hausman test was applied to determine which model is more appropriate (i.e., random vs. fixed effect). The Hausman test result was statistically significant, indicating that this test rejected the null hypothesis. Therefore, the fixed model is found to be more appropriate for the panel data used for the study. In addition, this research uses a time dummy because a degree of freedom problem occurs with regional dummies.

In general, panel data with two time periods use first-difference estimation because of the advantages mentioned above. However, this research cannot use first-difference estimation because many observations of the number of employment centers variable are unchanged over time. This can create estimation bias from a time-invariant variable. Therefore, this research uses pooled OLS with a time dummy variable (fixed effects regression).

Another goal of this study is to estimate the relationship between urban containment policies, urban sprawl, employment center formation, and urban commuting across income groups[5]. This can be estimated by the last equation in the recursive model. The equation is as follows:

$$Y_{3ji} = \beta_{30} + \beta_{31}\hat{Y}_{1i} + \beta_{32}\hat{Y}_{2i} + \gamma_{32}T_i + \gamma_{32}C_i + u$$

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5 This study simplifies income groups. U.S. Census Bureau divided income groups into five categories. Based on this data, this research created three groups; low income, median income, and high income. In 2000, household income under $20,000 comprised the low income group and household income between $20,001 and $75,000 comprised the median income group, and household income over $75,000 comprised the high income group. In 2010, household income under $25,000 comprised the low income group and household income between $25,001 and $100,000 comprised the median income group, and household income over $100,000 comprised the high income group. In the case of low income group in 2000 and 2010, the actual household income totaled $17,900 and $20,000, respectively. However, the low income value uses reference point $20,000 and $25,000 (versus $17,900 and $20,000) because of the limitation of data in CTPP.
Source: US Census Bureau. "Historical Income Tables: Households."
http://www.census.gov/hhes/www/income/data/historical/household/index.html

Where,

Y_{3ji} = Commuting Time of j income group in i MSAs ;

$\hat{Y}_{1i}$ = Predicted Sprawl Index in i MSAs;

$\hat{Y}_{2i}$ = Predicted Number of Employment Centers in i MSAs;

T_i = Time Dummy in i MSAs;

C_i = Control Variables in i MSAs;

u = Error term.

Control variables may be related to urban commuting and must be taken into account in analyzing the relationships between urban containment policies and urban commuting to minimize a confounding of results. The control variables are divided into three categories: (1) economic factors (2) social factors, and (3) a group of regional variables. Table 5 shows each grouping.

Table 5. Control Variables

Economic Factors	Median household income (dollars), Median housing value (dollars), Proportion of industries (% Primary, Secondary, Tertiary, Quaternary,, and Quinary Industry)[6], Gross domestic product (GDP)[7]
Social Factors	Mode choices (%), Population, Proportion of Population (% by age cohort), Population density (population per acre; in thousands), Employment density (workers per acre; in thousands), Proportion of education (% high school, undergraduate, graduate) Owner-occupied housing units Rent-occupied housing units
Regional Factors	Urbanized Area Region Dummies (Northeast, Midwest, South, West)

Beyond the issues discussed above, there are several limitations of the recursive system approach that need to be acknowledged. From the standpoint of external validity, the recursive structure relies on a correspondence to an underlying urban development theory. While the hierarchical model structure specified for this study is generally consistent with relevant theories of the urban development process (Fugita and Ogawa, 1982; Henderson, 1998), there is no way to test or ensure that the chosen structure is

6 The industries are divided into five categories: 1) Primary Industry is agriculture; 2) Secondary Industry is construction and manufacture; 3) Tertiary Industry is wholesale, retail, transportation, finance, and armed force; 4) Quaternary Industry is information, professional, education, public, and other service; and 5) Quinary Industry is arts.

7 Source: U.S. Bureau of Economic Analysis. http://www.bea.gov/regional/index.htm

optimal in any rigorous sense. Nevertheless, the model's performance indicators do offer some insight into the overall strength of the correspondence between the specified recursive structure and underlying theory of urban development.

With respect internal validity issues, an effort has been made to identify control variables in the recursive system to minimize the prospect of omitted variable bias. This effort may not have been fully successful. For example, in the recursive system's commuting equation it would have been preferable to use data on highway and transit system capacity and operational performance, but such data were not available at the necessary spatial scales. As a result, modal share data are used, recognizing that these data may not proxy commuting travel as well.

3.2.2 Indexes and GIS Techniques for Analysis

In addition to the statistical techniques, this research utilizes the J-H ratio, the urban sprawl index (USI), the urban containment index (UCI), and identification of employment centers. It applies GIS techniques to measure the J-H ratio using census tract data.

3.2.2.1 Jobs-Housing Ratio and GIS Techniques: The Floating Catchment Area Method

Levine (1998) discussed that the notion of J-H balance is ascribed to Ebenezer Howard's (1902) "garden cities." Wang (2000) defined J-H balance as "the (dis)parity between the number of jobs and housing units within a geographical area." In addition, Levine (1998) noted that the number of jobs and the number of housing units are to be equally balanced in cities in equilibrium. Burby and Weiss (1976) also defined a balanced region as "a self-reliant one, within which people live, work, shop, and recreate."

The J-H ratio is used as a measure of J-H balance in a region or area. If the value of the J-H ratio is close to 1, this represents a balance of jobs and housing. If the value of the J-H ratio is close to 0 or significantly more than 1, this represents an imbalance. However, there are no absolute values that represent a J-H balance. Margolis (1973) suggests that when the range of the ratio of jobs to housing units in a region is from 0.75 to 1.25, the J-H ratio of the area is balanced. Frank (1994) defines balance within census tracts as a J-H ratio of between 0.8 and 1.2. On the other hand, Cervero (1989) asserts that when the J-H ratio is around 1.5, the area is balanced, because there are often two or more workers in one household. Recently Park and Kwon (2009) have proposed and tested the range from 1.0 to 1.5 as a balanced range for the J-H ratio.

Weitz (2003) reports that the most common measurement options for calculating the J-H ratio include the following:

1. Jobs-housing units ratio (which includes vacant housing units).

2. Jobs-households ratio (also known as the jobs-occupied housing units ratio).

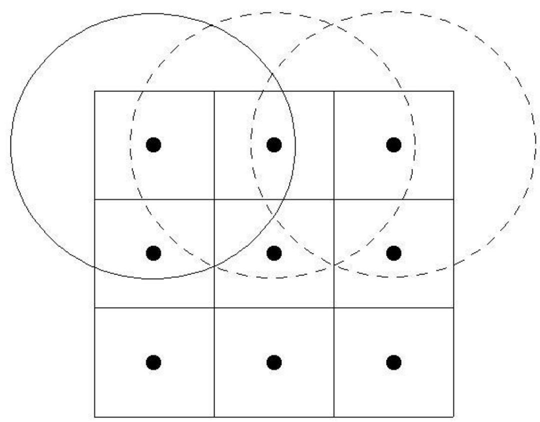
3. Jobs-employed residents ratio (also known as the jobs-labor force ratio).

According to Weitz (2003), the best of the J-H metric alternatives is jobs-employed residents (i.e., the number of resident workers—the actual labor force), if data are available, because "the goal of a jobs-housing balance policy is usually to match the number of working opportunities (jobs) with the number of living opportunities (housing units) in a given area (p.20)." He also recommended caution when the other methods are used to estimate the J-H ratio. "If, for example, a community relies on the number of housing units or households to represent demand for working opportunities in a measure of jobs-housing balance, that measure may inaccurately represent the actual number of workers living in a community: one housing unit or household may consist of any number of workers, or it may consist of no workers (p.20)."

The manner in which one calculates jobs-housing ratios depends on the data available (Weitz, 2003). This research uses jobs-households ratio because the data by income groups (needed for assessing distributional outcomes) are only available for households. The jobs-housing ratio (J-H ratio) for this research is formulated as follows:

$$JH\ Ratio_i = \frac{Number\ of\ Jobs_i}{Number\ of\ Households_i}$$

This research uses the floating catchment area method (FCA), a GIS technique developed by Peng (1997), for measurement of J-H ratios within possible commuting distances from a particular area (Figure 5). The FCA for measuring the J-H ratio is a census tract's[8] area whose houses and jobs are captured by the buffer (a circle around its centroid) (Peng, 1997; Wang, 2000; Park and Kwon, 2009). This buffer floats from one census tract to another while its radius remains the same. In practice, the floating catchment area is composed of the census tracts whose centroids fall within the buffer. The J-H ratio is measured by "the availability of jobs within a certain distance of a residential site, and the ratio of resident workers per job can be calculated for each census tract" (Wang, 2000). A reasonable range for defining catchment areas is usually 5.0 - 12.5 miles (Peng, 1997; Wang, 2000; Park and Kwon, 2009).



Note: The circle denotes a floating catchment area. The rectangle with a dot at its center represents a tract centroid.

Figure 5. The Floating Catchment Area Method for Measuring the J-H Ratio

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8 Horner and Murray (2002) found through a simulation that using disaggregated analysis zones can reduce the variation of results. When measuring or evaluating a J-H ratio, spatial scale effects can occur (the modifiable areal unit problem (MAUP)). For example, J-H ratios for large metro regions are more balanced than those derived from regional subareas. Therefore, this research choose census tract for measuring the J-H ratio to reduce MAUP.

3.2.2.2 Urban Sprawl Index (USI)

As has been discussed in the literature review, urban sprawl is "uncontrolled suburbanization" (Lee and Leigh 2005). The meaning of uncontrolled suburbanization could be explained as the inefficiency of urban residential land use because most sprawl areas consist of housing. Although an urban area grows, there will be less sprawl in a region if the growth is 'appropriately' controlled.

What, then, is the indicator to measure urban sprawl? This is represented as the J-H ratio, which has been interpreted in the literature as a 'viable' tool of urban spatial mismatch of socioeconomically-embedded employment and residential opportunities. For instance, if a region is balanced, social problems arising from urban sprawl are expected to decrease to some extent. To synthesize previous studies, Park and Kwon (2009) have recently re-confirmed its viability, by comparing the relationship between J-H ratio and commuting time in three case study areas.

In this research, the USI is constructed by the operationalization of the central tendency and dispersion of the J-H ratio in relation to commuting time. This research defines and utilizes the USI for formulating a scaled criterion of the degree of urban sprawl in the U.S. based on the coefficient of variation[9] (i.e., the coefficient of variation (CV) is selected as indicator of spatial variability). The USI is formulated as follow:

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9 The CV is a measure of variability relative to the mean.

$$USI_i = \left(\frac{CV_i^{jhr}}{CV^{jhr}}\right) \Big/ \left(\frac{CV_i^{ct}}{CV^{ct}}\right); \qquad CV = \frac{\sigma}{\mu},$$

Where,

CV_i^{jhr} = the coefficient of variation of the J-H ratio in metropolitan area i;

CV^{jhr} = the coefficient of variation of the J-H ratio in all metropolitan areas;

CV_i^{ct} = the coefficient of variation of commuting time in metropolitan area i;

CV^{ct} = the coefficient of variation of commuting time in all metropolitan areas;

μ = mean;

σ = standard deviation.

3.2.2.3 Urban Containment Index (UCI)

Wassmer (2006) divided urban containment policy into four categories: 1) Strong containment with accommodating future growth; 2) Strong containment with restrictive future growth; 3) Weak containment with accommodating future growth; and 4) Weak containment with restrictive future growth. In addition, Wassmer (2006) considered statewide growth management programs. Based on Wassmer's (2006) study, this research employs an urban containment index (UCI) as a measure of the strength of urban containment policy and planning interventions. The four categories have values from 1 to 4, and the existence of a statewide growth management program is assigned a value of 5.

The UCI is formulated as follows:

$$UCI_i = T_i * (SCA_i + SCR_i + WCA_i + WCR_i + SGM_i)$$

where,

SCR_i = strong containment with restrictive future growth (maximum: 4);

SCA_i = strong containment with accommodating future growth (maximum: 3);

WCR_i = weak containment with restrictive future growth (maximum: 2);

WCA_i = weak containment with accommodating future growth (maximum: 1);

SGM_i = statewide growth management program (The maximum of the metropolitan in the state is 5 if there is a program in a state. The value the metropolitan in the state is 0 if there is no program in a state.);

T_i = cumulative years after the year of the region's first implementation of containment intervention.

3.2.2.4 Employment Center Identification

There are two main approaches for employment subcenter identification. The first is a single minimum density cutoff point method (Giuliano and Small, 1991; Small and Song, 1994; McMillen and McDonald, 1998; Cervero and Wu, 1998; Bogart and Ferry, 1999). The second is a nonparametric method (McMillen, 2001, 2003; Craig and Ng, 2001). Neither method considers the spatial relationship between adjacent census tracts. Therefore, this study will use the Local Indicators of Spatial Association (LISA) technique developed by Anselin (1995). The LISA can estimate a spatial autocorrelation value for each unit (i.e., census tract) by calculating the local Moran's I. Therefore, the LISA can be used to identify local clustering such as positive autocorrelation (i.e., similarity) and negative autocorrelation (i.e., dissimilarity) (Nelson and Boots, 2008). The LISA is formulated as follows:

$$I_i = \frac{(X_i - \overline{X})}{\frac{1}{n}\sum_i (X_i - \overline{X})^2} \sum_j w_{ij}(X_j - \overline{X})$$

Where,

n = the total number of locations;

X_i = the value of the variable of interest, X, at location i;

X_j = the observation at neighboring locations j;

$\overline{X}$ = the sample average of X;

W_{ij} = the spatial weights matrix.

This study uses the minimum cutoff point method because LISA only indicates the spatial relationship between each unit (i.e., census tract). This study follows the cutoff points of previous studies (McDonald, 1987; McDonald and McMillen, 1990; Giuliano and Small, 1991) as follows: Density = 10 jobs/acre or Jobs = 10,000 jobs.

3.3 Research Hypotheses

Peng (1997), Wang (2000), and Park and Kwon (2009) posited and tested the following two research hypotheses:

Hypothesis 1: The J-H ratio will take an 'L' shape when commuting time decreases. This hypothesis formulates *a trade-off of the opportunity cost of commuting and employment opportunities*.

Hypothesis 2: Cities with a growth management policy will be less suburbanized. This hypothesis means that *planning interventions and growth management polices will help* offset more slowly increasing opportunity costs of commuting time by faster-increasing employment opportunities, towards a higher (or balanced) J-H ratio.

This research uses household-based data. Thus, if more jobs would provide more employment opportunities for local residents, commuting time will decrease, and the jobs-housing ratio will be negatively related to commuting time (Peng, 1997). Thus, commuting time will decrease in an area when more employment opportunities are provided.

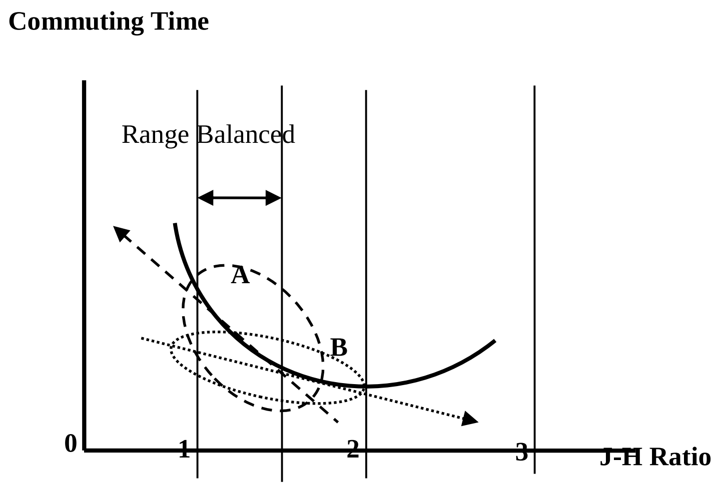

Figure 6. A Trade-Off of Opportunity Cost of Commuting Time and the J-H Ratio

Figure 6 illustrates how the two hypotheses are represented in the trade-off relationship of commuting time and J-H balance. Over most of the J-H range of values the figure shows a non-linear negative relationship between the jobs-housing ratio and commuting time. The points along the arc represent the trade-off of opportunity cost of commuting time (or costs) against higher preference (or incentive) for employment or lower preference (or incentive) for residence at a given location. At lower jobs-housing ratio values, the marginal opportunity cost of commuting time is assumed to increase rapidly (and be distributed) against more slowly decreasing employment opportunities as indicated by a roughly dotted tangent line onto the ‘L’ curve (and by the roughly dotted circle A) in Figure 6. Therefore, the roughly dotted circle (A) denotes the expected observed distribution of household units in the case where people are willing to pay marginally greater commuting (opportunity) costs. An area with distribution (A) is seen as a ‘housing-rich’ region. At the metropolitan level (not sub-metropolitan level), this type of region is more likely to have either (increasingly) housing-rich suburban centers or inner-city blight (and deteriorating inner-ring suburbs). In this study, therefore, a more sprawled region is expected to have a distribution like (A). Thus, an area with distribution (A) is typically an uncontrolled suburban area, as Lee and Leigh (2005) observed.

Alternatively, toward the upper end of J-H ratio values in Figure 6, the marginal opportunity cost of commuting time is shown to increase more slowly, as indicated by the smoothly dotted tangent line. The smoothly dotted circle (B) denotes the expected observed distribution of household units in the case where people are ‘less’ willing to pay additional commuting (opportunity) cost. The area within (B) is seen as a ‘job-rich’ region. At the metropolitan level, this type of region is more likely to have (increasingly) job-rich employment centers with less decentralization.

The highest values of J-H ratio in Figure 6 reflect commuting cost increases resulting from increasing congestion. An area with distribution (B) may also be a growth controlled suburban area, as Lee and Leigh (2005) mentioned. The distribution, A, implies that employment opportunities dominate residential opportunities, while the distribution, B, implies the reverse.

The functional relationship between commuting time and the J-H ratio can also be developed for different income groups, as shown in Figure 7. In the figure, area **A** represents the land use pattern for the high income group, indicating their preference for housing-rich locations. Area **B** represents the more mixed land use pattern of the middle income group, indicating that, as “rational locators,” their residential location choices will be more sensitive to the relationship between housing and transportation cost trade-offs. Area **C** represents the more jobs-rich land use pattern of the low-income residents. Their travel times can be shorter, longer or similar to middle income group. Although they live in job rich areas, one reason lower-income residents’ travel time may be longer or similar to the median income group is that they are more likely to use public transportation. Another reason may be that the jobs for which their skills are most suited are not very accessible (Sawicki and Moody, 2000). Therefore, this spatial mismatch can cause costly commutes. Alternatively, their travel times can be shorter because low income group lives in job rich areas and are able to reach many jobs without difficulty by either car or public transit (Blumenberg and Ong 2001). Lastly, although lower-income households may want to move their residence to be closer to their job or to reduce transportation costs, they cannot because of income constraints, high moving costs or various forms of segregation.

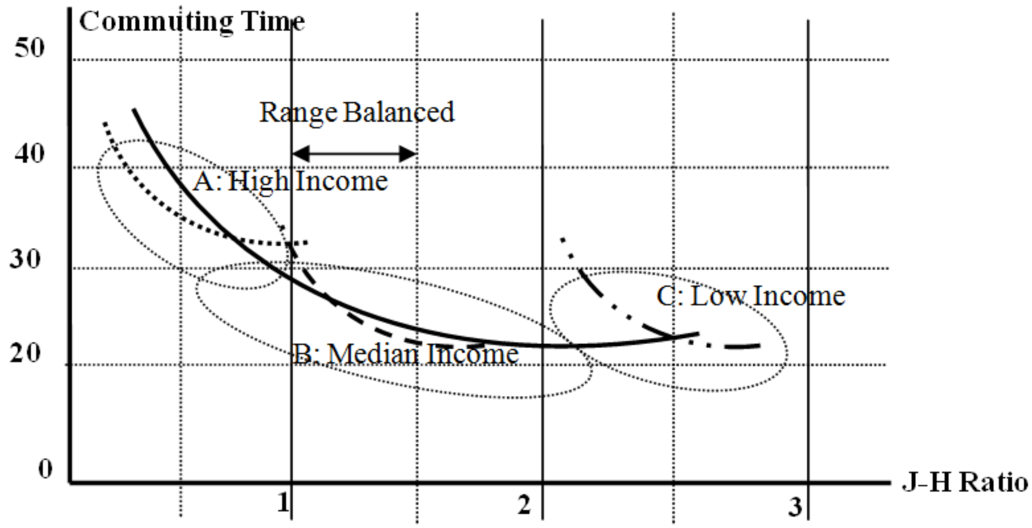

Figure 7. The Functional Relationship Between Commuting Time and J-H Ratio of Different Income Groups

Based on the above frameworks, this research addresses the following six hypotheses:

Hypothesis 1 (a trade-off of opportunity cost of commuting and employment opportunities.)

H_0: The J-H ratio will not take an 'L' shape when commuting time decreases.

H_1The J-H ratio will take an 'L' shape when commuting time decreases.

Hypothesis 2 (the effect of urban containment policies on urban sprawl)

H_0: Urban containment policies will not affect urban sprawl.

H_1: Urban containment policies will affect urban sprawl.

Hypothesis 3 (the effect of urban containment policies on employment centers)

H_0: Urban containment policies will not affect the incidence of employment centers.

H_1: Urban containment policies will affect the incidence of employment centers.

Hypothesis 4 (the effect of urban containment policies on commuting)

H_0: The effect of urban containment policies on urban commuting will not be statistically significant.

H_1: The effect of urban containment policies on urban commuting will be statistically significant.

Hypothesis 5 (the effect of urban containment policies on the commuting of different income groups)

H_0: The effect of urban containment policies on urban commuting of different income groups will not be statistically significant.

H_1: The effect of urban containment policies on urban commuting of different income groups will be statistically significant.

Hypothesis 6 (the effect of urban containment policies on density)

H_0: The effect of urban containment policies on the density of land use will not be statistically significant.

H_1: The effect of urban containment policies on the density of land use will be statistically significant.

Hypothesis 1 in this research tests whether the findings of Park and Kwon (2009) are valid by extension to all MSAs in the U.S. Therefore, *hypothesis 1* in this research can generalize a trade-off of the opportunity cost of commuting and employment opportunities by analyzing the relationship between the J-H ratio and commuting time.

The primary purpose of urban containment policy is to control urban sprawl. Therefore, *hypothesis 2* tests whether urban containment policies affect urban sprawl by analyzing the relationship between the UCI and the USI. The relationship between the level of urban containment policy or planning intervention and urban sprawl is expected to have a "U-shape" relationship. The reason for the U-shape is, as Brueckner (2000, p. 161) observed: "If only mild measures are needed to restrict urban growth that is slightly excessive, but draconian measures are used instead, consumers are likely to end up worse off (p.161)." That is, excessive urban containment policies can potentially have negative effects on urban sprawl. According to Brueckner (2000), strong containment programs to remedy urban sprawl can needlessly restrict the size of the city and lead to an escalation in housing costs and unintended development spillover effects. For example, according to Jun (2004), one consequence of Portland's UGB is that the less restrictive Clark County, Washington attracted an increasing share of the metropolitan region's new housing construction. One consequence of this spillover of development activity was an increase in commuting time. Figure 8, which shows the expected relationship between the USI and the UCI, reflects these unanticipated development spillover effects at "excessive" levels of urban containment.

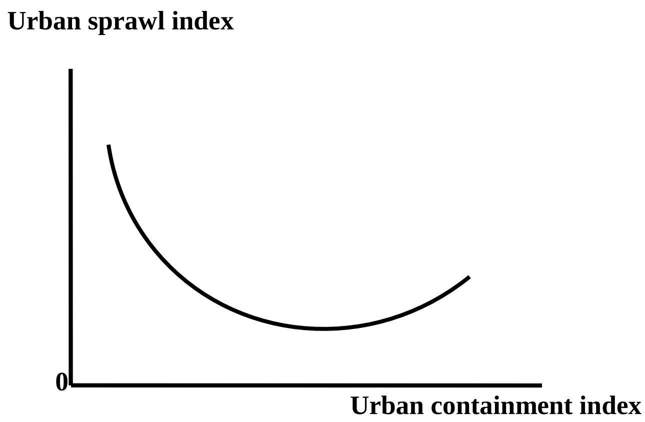

Figure 8. The Relationship Between the USI and the UCI

Hypothesis 3 can confirm the effects of urban containment policies on the incidence of employment centers. While growth containment has been found to contribute to central city revitalization, its effects on the formation of employment centers are less certain. Thus, this hypothesis addresses whether employment centers are more likely to form in compact or sprawl type settings.

Hypothesis 4 tests the urban containment policy effect on urban commuting by analyzing the relationship between UCI, USI, and commuting time from 2000 to 2010 in all MSAs. In general, urban sprawl results in longer distance commutes and greater commuting time. As a result, constraining urban sprawl can reduce commuting distance and time. Thus, this research can analyze the relationship between urban containment and commuting time.

Hypothesis 5 addresses the differing effects of urban containment policy on urban commuting of different income groups.

In addition, this research analyzes the relationship between the UCI and population and employment density. As discussed in the literature review, urban containment policies have been found to increase density. Therefore, the relationship between the level of urban containment policy and density (population and employment) is expected to be positive. Figure 9 shows the expected relationship between the density and the urban containment policy.

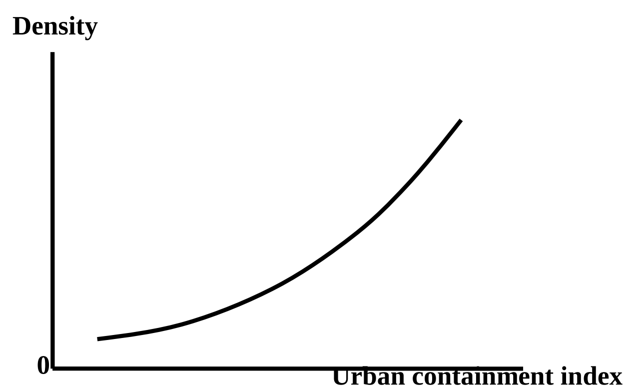

Figure 9. The Relationship Between Density and the UCI

CHAPTER IV

ANALYSIS AND FINDINGS

4.1 Descriptive Statistics

Tables 6, 7, and 8 present the descriptive statistics of the model's variables for census tracts, while Tables 9, 10, and 11 show descriptive statistics of the metropolitan level.

In the case of census tract level pooled data (Table 8), the average commuting time and the J-H ratio of all the MSAs are 26.41 minutes and 1.08, respectively. The commuting time and J-H ratio of the high, median, and low income tracts is 26.16, 27.48, 23.46, 0.28, 1.10, and 5.25, respectively. These values are consistent with the land use patterns of different income groups discussed in the previous chapter. High income groups tend to live in housing rich areas, while the low income groups live in job rich areas.

In addition, even though the average commuting time of the high income group is similar to the total average commuting time, the total average commuting time and the J-H ratio of all the MSAs is similar to the J-H ratio of the median income group in the all the MSAs (i.e., 27.48 and 1.10) because the standard deviation of the median income group commuting time is smaller than that of the high income group commuting time (i.e., 7.43 and 14.31). This means that the commuting time and the J-H ratio of the median income group dominates that of the all the MSAs.

Tables 6 and 7 show the descriptive statistics of the variables for census tract level in 2000 and 2010, respectively. The total average commuting increased from 26.22 to 26.56 minutes between 2000 and 2010 and the total J-H ratio remained constant at 1.08. The low and median income group commuting time also increased 0.24 and 0.40 minutes, respectively, while high income group commuting time decreased 1.02 minutes. The low income and median income group J-H ratio decreased from 5.45 to 5.07 and from 1.12 to 1.08, respectively, while the high income J-H ratio increased from 0.27 to 0.29 between 2000 and 2010. These changes to the J-H ratio within income groups can be regarded as an adjusting process of J-H distributions into the hypothesized level of improved balance (around J-H ratio 1).

In the case of metro level pooled data (Table 11), the total average commuting time and the total J-H ratio of all the MSAs is 22.44 minutes and 1.01, respectively. The commuting time of high, median, and low income groups is 22.02, 23.59, and 20.38 minutes, respectively. The J-H ratio of high, median, and low income groups is 0.21, 0.89, and 4.48, respectively. This pattern is similar to that of the census tract level. To examine this in more detail, a bivariate regression of commuting time and the J-H ratio is conducted.

Table 6. Descriptive Statistics of Variables for Census Tracts (2000)

Variables	N	Mean	Std. Dev.	Min	Max	Variables	N	Mean	Std. Dev.	Min	Max
Total Commuting Time	52,478	26.22	6.55	0	90.00	% of Primary Industry	52,351	0.02	0.06	0	1
Low Income Group Commuting Time	52,478	23.34	6.52	0	90.00	% of Secondary Industry	52,351	0.18	0.15	0	1
Median Income Group Commuting Time	52,478	27.27	7.26	0	90.00	% of Tertiary Industry	52,351	0.26	0.14	0	1
High Income Group Commuting Time	52,478	26.48	12.58	0	90.00	% of Quaternary Industry	52,351	0.45	0.19	0	1
Total JHR	52,474	1.08	0.49	0	10.06	% of Quinary Industry	52,351	0.08	0.08	0	1
Low JHR	52,469	5.45	2.96	0	116.34	% of Drive Alone	52,094	0.74	0.17	0	1
Median JHR	52,474	1.12	0.61	0	10.45	% of Carpool	52,094	0.12	0.06	0	1
High JHR	52,471	0.27	0.22	0	4.67	% of Public Transportation	52,094	0.07	0.13	0	1
Total JHR^2	52,474	1.41	1.45	0	101.28	% of Bicycle and Walk	52,094	0.03	0.06	0	1
Low JHR^2	52,469	38.51	83.02	0	13,535.34	% of Taxi, Others and Work at Home	52,094	0.04	0.03	0	1
Median JHR^2	52,474	1.62	2.14	0	109.21	% of 0 to 24 age	52,221	0.35	0.09	0	1
High JHR^2	52,471	0.12	0.27	0	21.83	% of 25 to 44 age	52,221	0.31	0.07	0	1
Employment Density	52,478	252.64	56,448.06	0	12,900,000	% of 45 to 64 age	52,221	0.22	0.06	0	1
Population Density	52,478	171.19	36,149.76	0	8,280,812	% of 65 above	52,221	0.12	0.08	0	1
Median Housing Value	52,478	143,051.50	109,263.70	0	1,000,001	% of High school degree	52,218	0.48	0.19	0	1
Median Income	52,478	46,465.85	22,162.47	0	200,000	% of Bachelor degree	52,218	0.43	0.14	0	1
Owner Housing Units	52,478	1,065.25	684.43	0	9,760	% of Graduate degree	52,218	0.09	0.09	0	1
Rent Housing Units	52,478	572.71	530.15	0	8,540						

Table 7. Descriptive Statistics of Variables for Census Tracts (2010)

Variables	N	Mean	Std. Dev.	Min	Max	Variables	N	Mean	Std. Dev.	Min	Max
Total Commuting Time	59,082	26.56	7.16	0	90.00	% of Primary Industry	58,763	0.02	0.06	0	1
Low Income Group Commuting Time	59,082	23.58	7.25	0	90.00	% of Secondary Industry	58,763	0.17	0.15	0	1
Median Income Group Commuting Time	59,082	28.07	7.56	0	90.00	% of Tertiary Industry	58,763	0.26	0.14	0	1
High Income Group Commuting Time	59,082	25.46	15.44	0	90.00	% of Quaternary Industry	58,763	0.46	0.19	0	1
Total JHR	59,048	1.08	0.51	0	24.21	% of Quinary Industry	58,763	0.09	0.09	0	1
Low JHR	59,038	5.07	3.19	0	246.25	% of Drive Alone	58,520	0.74	0.16	0	1
Median JHR	59,047	1.08	0.62	0	29.64	% of Carpool	58,520	0.10	0.06	0	1
High JHR	59,038	0.29	0.29	0	25.50	% of Public Transportation	58,520	0.06	0.13	0	1
Total JHR^2	59,048	1.43	4.28	0	586.23	% of Bicycle and Walk	58,520	0.04	0.07	0	1
Low JHR^2	59,038	35.88	328.80	0	60,639.06	% of Taxi, Others and Work at Home	58,520	0.05	0.04	0	1
Median JHR^2	59,047	1.55	5.85	0	878.70	% of 0 to 24 age	58,606	0.34	0.10	0	1
High JHR^2	59,038	0.17	3.77	0	650.25	% of 25 to 44 age	58,606	0.28	0.08	0	1
Employment Density	59,082	4.49	24.58	0	1,316.14	% of 45 to 64 age	58,606	0.26	0.07	0	1
Population Density	59,082	9.41	19.44	0	821.24	% of 65 above	58,606	0.13	0.08	0	1
Median Housing Value	59,082	250,253.90	188,542.20	0	1,000,001	% of High school degree	58,606	0.44	0.18	0	1
Median Income	59,082	57,688.49	28,783.22	0	248,905	% of Bachelor degree	58,606	0.47	0.13	0	1
Owner Housing Units	59,082	1,031.99	627.42	0	8,500	% of Graduate degree	58,606	0.10	0.09	0	1
Rent Housing Units	59,082	550.22	461.87	0	8,180						

Table 8. Descriptive Statistics of Variables for Census Tracts (Pooled Data)

Variables	N	Mean	Std. Dev.	Min	Max	Variables	N	Mean	Std. Dev.	Min	Max
Total Commuting Time	111,560	**26.41**	**7.07**	0	90	% of Primary Industry	111,114	0.02	0.06	0	1
Low Income Group Commuting Time	111,560	**23.46**	**7.10**	0	90	% of Secondary Industry	111,114	0.18	0.15	0	1
Median Income Group Commuting Time	111,560	**27.48**	**7.43**	0	90	% of Tertiary Industry	111,114	0.26	0.14	0	1
High Income Group Commuting Time	111,560	**26.16**	**14.31**	0	90	% of Quaternary Industry	111,114	0.46	0.19	0	1
Total JHR	111,522	**1.08**	**0.50**	0	24.21	% of Quinary Industry	111,114	0.09	0.09	0	1
Low JHR	111,507	**5.25**	**3.09**	0	246.25	% of Drive Alone	110,614	0.74	0.16	0	1
Median JHR	111,521	**1.10**	**0.61**	0	29.64	% of Carpool	110,614	0.11	0.06	0	1
High JHR	111,509	**0.28**	**0.26**	0	25.50	% of Public Transportation	110,614	0.07	0.13	0	1
Total JHR^2	111,522	1.42	3.27	0	586.23	% of Bicycle and Walk	110,614	0.04	0.06	0	1
Low JHR^2	111,507	37.12	245.94	0	60,639.06	% of Taxi, Others and Work at Home	110,614	0.05	0.04	0	1
Median JHR^2	111,521	1.58	4.50	0	878.70	% of 0 to 24 age	110,827	0.34	0.10	0	1
High JHR^2	111,509	0.15	2.75	0	650.25	% of 25 to 44 age	110,827	0.29	0.08	0	1
Employment Density	111,560	120.94	38,622.21	0	12,900,000	% of 45 to 64 age	110,827	0.24	0.07	0	1
Population Density	111,560	85.51	24,793.63	0	8,280,812	% of 65 above	110,827	0.13	0.08	0	1
Median Housing Value	111,560	199,825.70	165,242.30	0	1,000,001	% of High school degree	110,824	0.45	0.19	0	1
Median Income	111,560	52,409.34	26,479.78	0	248,905	% of Bachelor degree	110,824	0.45	0.13	0	1
Owner Housing Units	111,560	1047.64	655.07	0	9,760	% of Graduate degree	110,824	0.09	0.09	0	1
Rent Housing Units	111,560	560.80	495.29	0	8,540						

Table 9. Descriptive Statistics of Variables for Metropolitan Areas (2000)

Variables	N	Mean	Std. Dev.	Min	Max	Variables	N	Mean	Std. Dev.	Min	Max
Total Commuting Time	350	22.30	2.58	16.13	35.47	Employment Centers	350	1.43	2.77	0.00	30
Low Income Group Commuting Time	350	20.29	2.27	15.07	31.26	Urban Containment Index	350	16.46	42.64	0.00	296
Median Income Group Commuting Time	350	23.41	3.06	17.05	36.41	Urban Containment Index^2	350	2,084.14	8,817.76	0.00	87,616
High Income Group Commuting Time	350	22.29	4.13	13.40	37.46	Urban Sprawl Index	350	1.17	0.38	0.40	2.86
Total JHR	350	1.00	0.16	0.15	1.81	% of Primary Industry	350	0.02	0.02	0.00	0.15
Low JHR	350	4.61	1.39	0.67	9.23	% of Secondary Industry	350	0.21	0.07	0.07	0.53
Median JHR	350	0.89	0.24	0.09	2.03	% of Tertiary Industry	350	0.28	0.05	0.16	0.55
High JHR	350	0.20	0.06	0.02	0.46	% of Quaternary Industry	350	0.41	0.06	0.22	0.63
Total JHR^2	350	1.20	0.40	0.03	4.37	% of Quinary Industry	350	0.08	0.03	0.04	0.34
Low JHR^2	350	26.64	17.50	0.57	119.58	% of Drive Alone	350	0.80	0.04	0.53	0.89
Median JHR^2	350	1.01	0.59	0.01	5.47	% of Carpool	350	0.12	0.02	0.07	0.19
High JHR^2	350	0.06	0.06	0.00	0.56	% of Public Transportation	350	0.01	0.02	0.00	0.27
Population	350	656,093.70	1,508,555	52,457	18,300,000	% of Bicycle and Walk	350	0.03	0.02	0.01	0.13
Urbanized Areas	350	145,686.00	250,506.50	11,764.12	2,259,370	% of Taxi, Others and Work at Home	350	0.04	0.01	0.02	0.08
GDP (2001)	350	32,567.70	89,815.05	1,848	1,169,603	% of 0 to 24 age	350	0.36	0.04	0.20	0.55
Owner Housing Units	350	159,720.80	318,482.90	12,115	3,467,190	% of 25 to 44 age	350	0.29	0.02	0.19	0.36
Rent Housing Units	350	85,871.07	234,700.10	6,839	3,222,510	% of 45 to 64 age	350	0.22	0.02	0.13	0.27
Median Housing Value	350	106,461.60	48,766.35	46,863.64	436,652.50	% of 65 above	350	0.13	0.03	0.04	0.35
Median Income	350	40,245.77	7,371.41	25,868.75	77,897.82	% of High school degree	350	0.49	0.09	0.22	0.71
Total Jobs	350	303,992.30	689,159.70	4,867	8,115,347	% of Bachelor degree	350	0.43	0.07	0.26	0.61
Population Density	350	241.44	4,339.99	0.68	81,187.20	% of Graduate degree	350	0.08	0.04	0.03	0.27
Employment Density	350	365.78	6,776.35	0.07	126,777.00						

Table 10. Descriptive Statistics of Variables for Metropolitan Areas (2010)

Variables	N	Mean	Std. Dev.	Min	Max	Variables	N	Mean	Std. Dev.	Min	Max
Total Commuting Time	350	22.59	3.04	15.31	36.23	Employment Centers	350	1.49	2.82	0.00	28.00
Low Income Group Commuting Time	350	20.47	2.28	14.17	31.34	Urban Containment Index	350	27.61	65.14	0.00	420.00
Median Income Group Commuting Time	350	24.17	3.14	16.08	37.08	Urban Containment Index^2	350	4,993.63	17,839.61	0.00	176,400
High Income Group Commuting Time	350	21.37	4.44	11.44	37.54	Urban Sprawl Index	350	1.01	0.42	0.11	4.76
Total JHR	350	1.03	0.15	0.71	2.41	% of Primary Industry	350	0.02	0.03	0.00	0.17
Low JHR	350	4.35	1.25	2.17	11.88	% of Secondary Industry	350	0.19	0.06	0.09	0.48
Median JHR	350	0.90	0.21	0.49	1.95	% of Tertiary Industry	350	0.27	0.04	0.16	0.51
High JHR	350	0.23	0.08	0.11	0.82	% of Quaternary Industry	350	0.44	0.05	0.25	0.62
Total JHR^2	350	1.32	1.31	0.61	21.96	% of Quinary Industry	350	0.09	0.02	0.05	0.31
Low JHR^2	350	29.14	81.46	5.20	1,451.98	% of Drive Alone	350	0.79	0.05	0.50	0.87
Median JHR^2	350	1.13	1.76	0.31	31.80	% of Carpool	350	0.11	0.02	0.07	0.17
High JHR^2	350	0.13	0.77	0.01	14.21	% of Public Transportation	350	0.02	0.02	0.00	0.30
Population	350	736,249.20	1,635,058	55,274	19,600,000	% of Bicycle and Walk	350	0.03	0.02	0.01	0.18
Urbanized Areas	350	170,061.90	283,136.20	13,543.11	2,385,671	% of Taxi, Others and Work at Home	350	0.05	0.02	0.02	0.11
GDP (2011)	350	37,941.76	103,623.10	1,901	1,336,038	% of 0 to 24 age	350	0.35	0.04	0.20	0.52
Owner Housing Units	350	174,205.80	340,789.50	13,380	3,609,378	% of 25 to 44 age	350	0.26	0.02	0.17	0.33
Rent Housing Units	350	92,880.62	239,704.80	7,802	3,200,093	% of 45 to 64 age	350	0.26	0.03	0.15	0.32
Median Housing Value	350	176,753.70	94,135.20	67,230	641,599.10	% of 65 above	350	0.13	0.03	0.06	0.33
Median Income	350	49,505.42	9,215.44	30,360.48	90,940.40	% of High school degree	350	0.45	0.08	0.21	0.66
Total Jobs	350	333,222.40	756,861.40	27,325	8,851,708	% of Bachelor degree	350	0.47	0.06	0.30	0.66
Population Density	350	3.71	3.18	0.02	41.91	% of Graduate degree	350	0.08	0.03	0.03	0.21
Employment Density	350	1.98	1.51	0.36	19.87						

Table 11. Descriptive Statistics of Variables for Metropolitan Areas (Pooled Data)

Variables	N	Mean	Std. Dev.	Min	Max	Variables	N	Mean	Std. Dev.	Min	Max
Total Commuting Time	700	**22.44**	**3.01**	15.31	36.23	Employment Centers	700	1.46	2.80	0	30
Low Income Group Commuting Time	700	**20.38**	**2.28**	14.17	31.34	Urban Containment Index	700	22.03	55.30	0	420
Median Income Group Commuting Time	700	**23.59**	**3.11**	16.08	37.08	Urban Containment Index^2	700	3,538.89	14,136.42	0	176,400
High Income Group Commuting Time	700	**22.02**	**4.30**	11.44	37.54	Urban Sprawl Index	700	1.09	0.41	0.11	4.76
Total JHR	700	**1.01**	**0.16**	0.15	2.41	% of Primary Industry	700	0.02	0.03	0.00	0.17
Low JHR	700	**4.48**	**1.33**	0.67	11.88	% of Secondary Industry	700	0.20	0.07	0.07	0.53
Median JHR	700	**0.89**	**0.23**	0.09	2.03	% of Tertiary Industry	700	0.27	0.04	0.16	0.55
High JHR	700	**0.21**	**0.07**	0.02	0.82	% of Quaternary Industry	700	0.42	0.06	0.22	0.63
Total JHR^2	700	1.26	0.97	0.03	21.96	% of Quinary Industry	700	0.09	0.03	0.04	0.34
Low JHR^2	700	27.89	58.89	0.57	1,451.98	% of Drive Alone	700	0.80	0.05	0.50	0.89
Median JHR^2	700	1.07	1.31	0.01	31.80	% of Carpool	700	0.11	0.02	0.07	0.19
High JHR^2	700	0.09	0.55	0.00	14.21	% of Public Transportation	700	0.02	0.02	0.00	0.30
Population	700	696,193.10	1,572,703	52,457	19,600,000	% of Bicycle and Walk	700	0.03	0.02	0.01	0.18
Urbanized Areas	700	157,874.00	267,406.70	11,764.12	2,385,671	% of Taxi, Others and Work at Home	700	0.04	0.01	0.02	0.11
GDP	700	35,254.73	96,933.07	1,848	1,336,038	% of 0 to 24 age	700	0.36	0.04	0.20	0.55
Owner Housing Units	700	166,963.30	329,668.50	12,115	3,609,378	% of 25 to 44 age	700	0.28	0.03	0.17	0.36
Rent Housing Units	700	89,375.85	237,071.90	6,839	3,222,510	% of 45 to 64 age	700	0.24	0.03	0.13	0.32
Median Housing Value	700	141,607.70	82,757.30	46,863.64	641,599.10	% of 65 above	700	0.13	0.03	0.04	0.35
Median Income	700	44,875.60	9,539.25	25,868.75	90,940.40	% of High school degree	700	0.47	0.09	0.21	0.71
Total Jobs	700	318,607.30	723,432.40	4,867	8,851,708	% of Bachelor degree	700	0.45	0.07	0.26	0.66
Population Density	700	122.57	3,068.95	0.02	81,187.20	% of Graduate degree	700	0.08	0.03	0.03	0.27
Employment Density	700	183.88	4791.64	0.07	126,777.00						

4.2 Bivariate Regression Analyses

The bivariate regression models are estimated to analyze the functional relationship between J-H ratio and commuting time. Table 12 shows two bivariate regression models for the metro level and the census tract level data, respectively.

All models at the metro level are statistically significant in terms of the overall *F*-test (p = .050), with R^2, .016 (high income model), .090 (median income model), and .009 (low income model), respectively. In addition, all models at the census tract level are statistically significant in terms of the *F*-test (p = .000), with R^2, .042 (high income model), .045 (median income model), and .039 (low income model), respectively.

The coefficients of the JHR and JHR^2 variables in the metro level model are not statistically significant except the JHR^2 in median income group. On the other hand, all regression results of all income groups in the census tract model show that the JHR and JHR^2 are statistically significant at $\alpha < .01$. The coefficient of the JHR in all income groups is negative, but the coefficient of the JHR^2 in all income groups is positive. These results indicate that the functional relationship between commuting time and J-H ratio has a trade-off relationship similar to that shown in Figures 6 and 7. This result supports *hypothesis 1* of this research.

The coefficient slopes of the JHR and JHR^2 in each income group can explain the urban spatial structure of the different income groups. The high income group with the steepest slope and low J-H ratio locates in housing rich areas because they are less affected by transportation costs. That is, in the case of the high income group, the living environment in their residential area is a more important factor than transportation costs.

On the other hand, the low income group with a gentle slope and high J-H ratio locates in job rich areas. The low income group did not select their residential location as a "rational locator" because of the socioeconomic conditions discussed earlier.

In addition, the median income group with an intermediate slope and balanced J-H ratio locates in J-H balanced areas, indicating that they decide their residential location as the trade-off relationship between transportation costs and housing prices. Therefore, the median income group can also be regarded as a "rational locator" (Levinson & Kumar, 1994).

Although other independent variables were not included in the model, these results clearly support *hypothesis 1* and the functional relationship between commuting time and J-H ratio of different income groups in Figure 7 (as in Figure 10).

The R^2 of the median income group is higher than for other income groups. The results indicate that the median income group regards the relationship between commuting costs and residential location as an important factor. On the other hand, the R^2 of high and low income groups is lower. That is, their residential location is more affected by other factors. As mentioned above, when the high income group decides on their housing, they focus on the living environment in a residential area. But when the low income group decides on their housing, they are more affected by other factors, such as high moving costs, lower income and other conditions.

Figure 10 shows the scatter plot of the J-H ratio (X) and commuting time (Y) of each income group at the metro level[10]. The slope and shape of distribution in the graph (a) shows a pattern, supporting *hypothesis 1* and the functional relationship between commuting time and J-H ratio of different income groups in Figure 7.

Graph (a) in Figure 10 and the first graph in Figure 10 (b) show the urban spatial distributions of high income groups, indicating that they tend to locate in housing rich areas. This also indicates that the high income group is willing to pay the more expensive commuting (opportunity) cost. The graphs also indicate that the residential location of high income group can cause urban area expansion termed '*geographic sprawl*' because their spatial distribution is an example of uncontrolled suburbanization.

In contrast with the high income group, the urban spatial distributions of the low income groups show (Figure 10 graph (a) and third graph in Figure 10 (b)) that they tend to live in job rich areas. This indicates that the low income group is 'less' willing to pay expensive commuting (opportunity) cost. The descriptive analysis indicates that the average commuting time of low income group is shorter than that of median income group, likely because they live in job rich areas and are able to access jobs by auto or transit without great difficulty (Blumenberg and Ong 2001). However, figure 10 (a) also shows that the average commuting time of low-income households in some metro areas is longer or similar to the median income group. For these metro areas, mismatch problems and/or barriers to relocation may be more prevalent.

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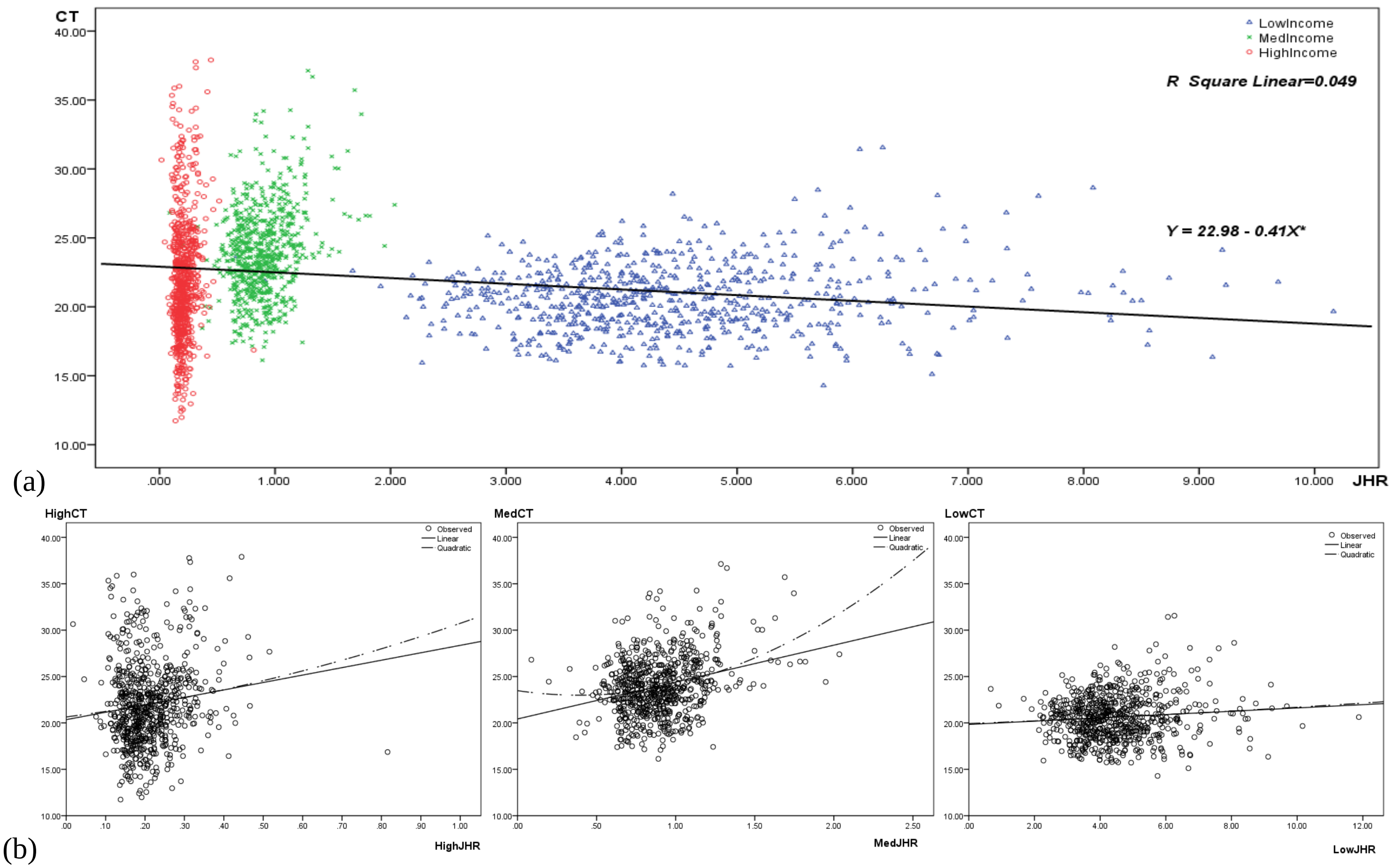
10 In the case of census tract level, it is hard to show a scatter plot figure because there are many observations (111,560). Therefore, this research uses metro level data to show the scatter plot of the J-H ratio and commuting time.

Figure 10 graph (a) and the second graph in Figure 10 (b) show the urban spatial distributions of the median income groups, indicating that they tend to live in J-H balanced areas. Thus, their residential locations are more influenced by the trade-off relationship between transportation costs and housing prices as a “rational locators” (Levinson & Kumar, 1994). As a consequence, the median income group might attenuate or lessen urban sprawl depending on their residential location preferences.

Table 12. Regression Results for the Relationship Between Commuting Time and JHR of Each Income Group in Metro and Census Tract Level

Independent Variable	Dependent Variable											
	Metro Level						Census Tract Level					
	High Income Group Commuting Time		Median Income Group Commuting Time		Low Income Group Commuting Time		High Income Group Commuting Time		Median Income Group Commuting Time		Low Income Group Commuting Time	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t
Constant	20.644*	21.40	23.478*	19.97	19.930*	25.50	29.9473*	443.63	31.0987*	611.69	26.4979*	582.92
JHR (Each Group)	5.557	0.78	-2.528	-1.07	0.138	0.45	-13.4102*	-69.87	-3.2111*	-69.08	-0.53627*	-66.71
JHR^2 (Each Group)	4.535	0.36	3.253*	2.83	0.004	0.13	0.55647*	30.62	0.1514*	23.95	0.00265*	26.27
N	700		700		700		111509		111521		111507	
F	(2, 697) = 5.777		(2, 697) = 34.298		(2, 697) = 3.241		(2,111506) = 2466.70		(2,111518) = 2655.22		(2,111504) = 2287.53	
Prob > F	.003		.000		.040		0.0000		0.0000		0.0000	
R^2	.016		.090		.009		0.042		0.045		0.039	

* : Coefficient is significant at the 0.01 level.   **: Coefficient is significant at the 0.05 level.



* : Coefficient is significant at the 0.01 level. Each dot represents one metropolitan area of each income group.

Figure 10. Bivariate Regression Plots of Commuting Time (Y) and the J-H Ratio (X) by income group for Metro Level Pooled Data

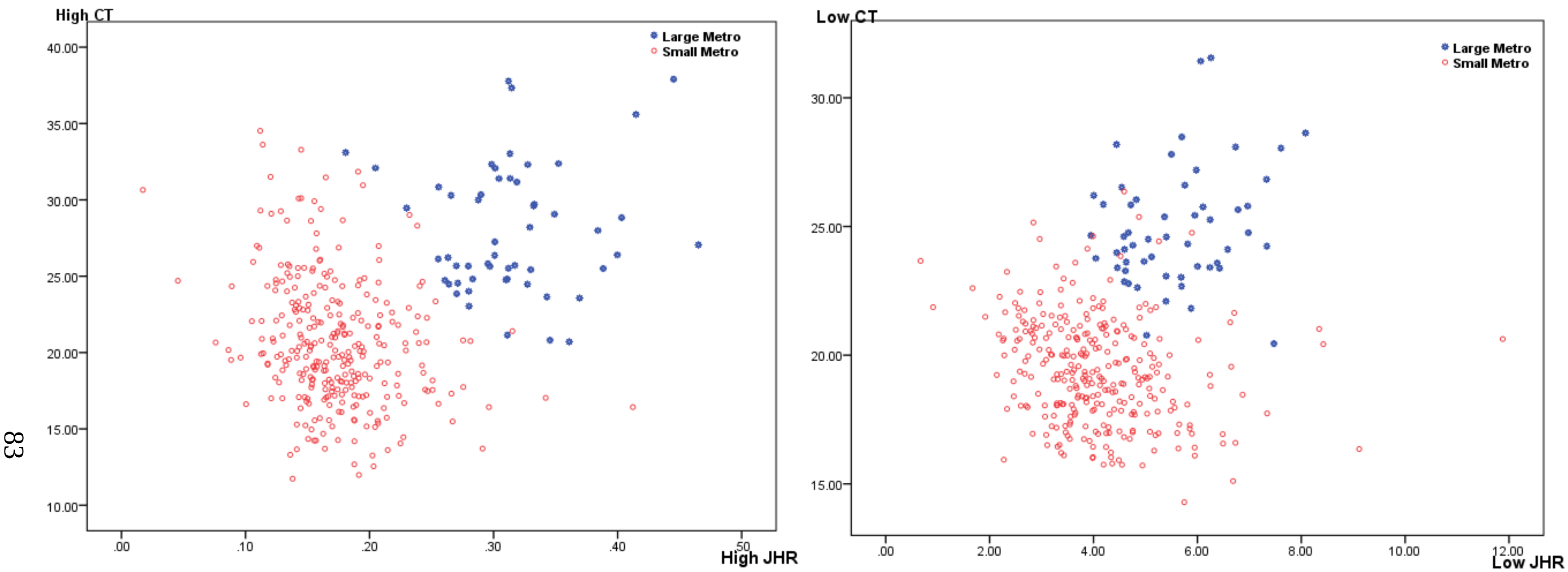
4.3 The Relationship Between J-H Balance and Commuting According to Metropolitan Size

Figure 11 shows the relationship between J-H balance and commuting time of high and low income groups (graph (a) and graph (b), respectively) according to metropolitan size[11].

The J-H ratios and commuting times of each income group in large metropolitan areas are higher and longer, while that of each income group in small metropolitan areas is lower. That is, the dots of both income groups in large metropolitan areas are concentrated in Quadrant 1 of the graph. The dots of both income groups in small metropolitan areas are concentrated in Quadrant 3 of the graph.

In addition, Weitz (2003) defined a J-H imbalance typology, as shown in Table 13 to improve the efficacy of J-H balance policy by matching an appropriate response with each type of imbalance.

11 Large metropolitan areas include population over 2,000,000 and small metropolitan areas include population under 200,000.



(a) (b)

Figure 11. Bivariate Plots of Commuting Time (Y) and the J-H Ratio (X) of High and Low Income Group by Metropolitan Size

Table 13. Types of J-H Imbalance

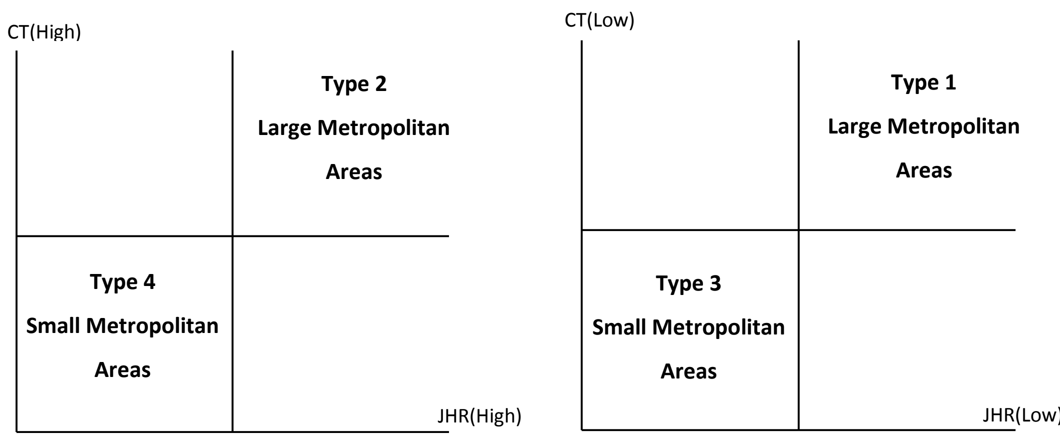
Type of Imbalance	Jobs	Housing Units	Example	Method of Response
Type 1	Too many low-wage	Too few low-end	Suburban employment centers (or edge cities)	Needs more housing for low-wage workers
Type 2	Too many high-wage	Too few high-end	Downtown employment areas in central cities	Needs more housing for higher-wage workers
Type 3	Too few low-wage	Too much low-end	Older suburbs and central-city neighborhoods	Needs more employment opportunities for the resident, lower-wage, labor force.
Type 4	Too few high-wage	Too much high-end	High-income bedroom communities	The area is job-poor but has a highly skilled resident labor force

Source: Weitz (2003) p 5-6.

Based on Figure 10 and the Weitz (2003) J-H imbalance typology, the relationship between the type of J-H imbalance, commuting time, and J-H ratio of low and high income groups according to metropolitan size can be classified. Figure 12 shows the classification.

In the case of the high income group, the J-H ratios and commuting times in large metropolitan areas are higher and longer, representing Type 2 in the J-H imbalance typology. Although their residential location is close to high jobs, the reason for the relatively longer commuting time is that there is traffic congestion and they might use public transportation in large metropolitan areas. In contrast with large metropolitan areas, the J-H ratios and commuting times in small metropolitan areas are lower and shorter, representing Type 4 in J-H imbalance typology. The residential location of high income groups in small metropolitan is not in high job rich areas but in high housing rich areas. That is, they live in high-income bedroom communities. In addition, the reason for relatively shorter commuting time is that they live in smaller and less congested cities.

In the case of low income groups, the J-H ratios and commuting times in large metropolitan areas are higher and longer, indicating the Type 1 in J-H imbalance typology (e.g., suburban employment centers (or edge cities)). The reason for their longer commuting times is that their residential location is not only farther from their jobs (i.e., low jobs), but also their accessibility to public transportation is lower. On the contrary, the J-H ratios and commuting times in small metropolitan areas are lower and shorter, indicating the Type 3 in J-H imbalance typology (e.g., older suburbs and central-city neighborhoods). That is, their commuting time is shorter because their housing is closer to their jobs (i.e., low jobs).



(A) High Income Group (B) Low Income Group

Figure 12. Type of J-H Imbalance and Commuting Time and J-H Ratio of High and Low Income Group According to Metropolitan Scale

In other words, large metropolitan areas can cause the J-H imbalance of Type 1 and Type 2, and small metropolitan areas can cause the J-H imbalance of Type 3 and Type 4. Figure 13 shows the type of J-H imbalance according to metropolitan scale.

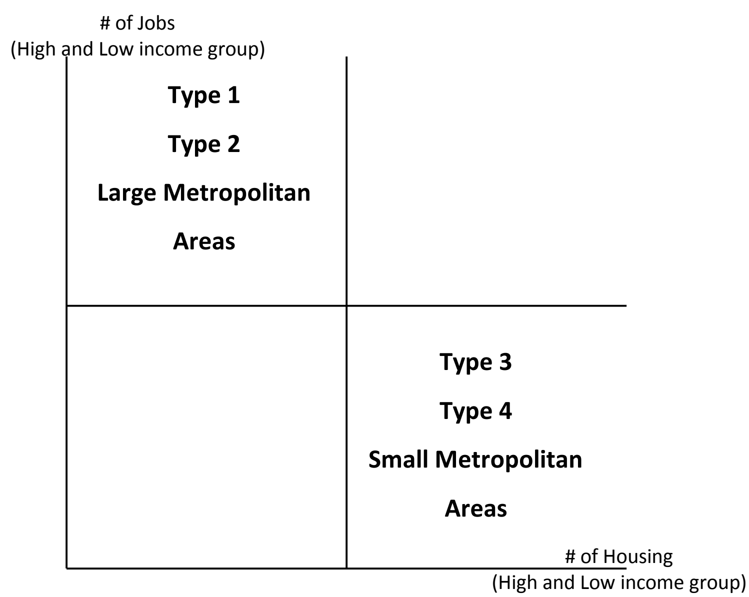


Figure 13. Type of J-H Imbalance According to Metropolitan Scale

4.4 The Relationship Between Commuting Time and J-H Balance

Four multiple regressions were conducted to test *Hypothesis 1* (*a trade-off of opportunity cost of commuting and employment opportunities*) with other variables. The first model represents the relationship between commuting time and the J-H ratio for all income groups. The other models represent that of each income group (i.e., High, Median, and Low income groups).

All models are statistically significant in terms of the *F*-test (p = .000) and show fair goodness of fit as indicated by R^2, .58 (total income model), .20 (high income model), .45 (median income model), and .51 (low income model), respectively.

Table 14 shows that variables representing JHR in all models are highly significant at $\alpha < .01$. Consistent with the bivariate regressions, the slope coefficients of the JHR in all models are negative and the coefficients of the JHR^2 in all models are positive. These signs support the observation that the relationship of J-H ratio and commuting using home-based data follows an "L" curve (Peng 1997; Park and Kwon 2009). The curvilinear relationship means that job rich and housing rich tracts have relatively longer commuting times. Therefore, these results support *hypothesis 1*. In addition, the slope coefficient of the JHR (-12.78) and JHR^2 (0.53) in high income model is the steepest of all the income models. In contrast with high income group, the slope coefficient of the JHR (-0.28) and JHR^2 (0.0014) in low income model is less steep than that of the other income groups, consistent with the functional relationship between commuting time and J-H ratio of different income groups shown in Figure 7.

The coefficients of the time dummy in all models are statistically significant at $\alpha < .01$, except for the median income group (at $\alpha < .05$). The coefficients in the total income group, median income group and low income group are positive, indicating an increase in average commuting time between 2000 and 2010. However, the coefficient of the high income group is negative, indicating a decrease in average commuting time between 2000 and 2010. This result may reflect the effects of gentrification, which is the transformation of neighborhoods from lower to higher value. Gentrifying areas are typically located in the urban core, near downtowns or other central employment locations. The higher income residents moving to these areas would thus likely gain greater accessibility to these employment centers and shorten their commuting time.

The median income variables of all models are highly significant at $\alpha < .01$, indicating that additional income would increase commuting time. Commuting is generally considered to be income elastic, with higher income urban residents willing to pay higher commuting costs in return for greater housing consumption (Muth 1969).

The owner-occupied housing units and rent-occupied housing units variables are highly significant at $\alpha < .01$ in all of the models. The slope coefficients of owner-occupied housing units in all models are positive, while the coefficients for rent-occupied housing units are negative, except for the high income group. The results indicate that homeowners are generally willing to pay higher commuting costs than renters. In other words, homeowners likely consider other factors more important in housing location choices. However, the coefficient of rent-occupied housing in the high income group is positive, indicating that even though they lived in rental housing, they consider other factors to be more important.

Previous studies similarly considered population or employment density (Peng 1997; Cevero1998; Wang 2000). In this analysis, the employment density variable was dropped because of multicollinearity. Therefore, the effect of population density can also be interpreted as an employment density effect. The population density variables of all models are statistically significant at $\alpha < .01$ with a negative sign. It can be interpreted that people in denser areas with more employment opportunities are more likely to have shorter commute times.

Most industry variables in all models are statistically significant. The primary industry variable as a reference category has relatively longer commuting time than the other industries because the workplace for agricultural jobs is generally farther away from housing. In addition, the tertiary and quaternary industries have longer commuting times relative to other sectors (i.e., secondary, and quinary industry) because the locations of service are sensitive to consumer demand.

Most transportation mode variables in all models are statistically significant at $\alpha < .01$, except the taxi, other and work-at-home variable. The bicycle and walk variable, as a reference category, has a relatively shorter estimated commuting time than the other transportation modes. In contrast, the public transportation mode has a relatively longer estimated commuting time.

The coefficients of the age cohort variables in all models are significant at $\alpha < .01$. The youngest cohort, the reference category in all models, has a relatively shorter commuting time than that of the older age groups (i.e., 24 to 44 age and 45 to 64 age). However, the coefficients of the over age 65 cohort in all models indicate relatively shorter commuting times than that of the other age groups. These results can be interpreted such that amenities and services are relatively more important location choice factors for middle age groups than proximity to work.

Educational attainment variables in all models are significant at $\alpha < .01$ except for the bachelor degree variable of high income group. People with a high school degree, the reference category in all models, have relatively longer commuting time than that of the other categories.

Table 14. Regression Results for Commuting Time at the Census Tract Level

Independent Variable	Dependent Variables							
	Total Commuting Time		High Income Group Commuting Time		Median Income Group Commuting Time		Low Income Group Commuting Time	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t
Constant	12.155840*	27.64	10.284060*	9.64	16.475280*	28.69	9.020305*	17.90
Median Income	0.000085*	64.84	0.000204*	71.14	0.000113*	63.18	0.000042*	24.97
Total JHR	-5.384637*	-20.95						
Total JHR^2	0.330927*	3.91						
High JHR			-12.782310*	-45.07				
High JHR^2			0.530941*	12.01				
Median JHR					-4.283301*	-15.07		
Median JHR^2					0.235665*	2.81		
Low JHR							-0.282105*	-27.72
Low JHR^2							0.001388*	4.74
Owner Housing Units	0.000757*	26.42	0.002385*	36.02	0.001285*	34.81	0.000627*	21.38
Rent Housing Units	-0.000451*	-10.54	0.001242*	12.30	-0.000485*	-9.16	-0.000158*	-3.21
Population Density	-0.0000005*	-54.56	-0.000001*	-31.00	-0.0000003*	-27.39	-0.000001*	-78.21
Time Dummy	0.457627*	13.53	-2.339344*	-25.31	0.083353**	1.98	0.670289*	16.64
% of Primary Industry	Dropped		Dropped		Dropped		Dropped	
% of Secondary Industry	-1.333845*	-4.08	-7.885801*	-9.60	-4.501923*	-10.56	-4.832023*	-15.16
% of Tertiary Industry	-0.767218**	-2.34	-7.580090*	-9.45	-3.935300*	-9.12	-4.969761*	-15.63

Table 14. Regression Results for Commuting Time at the Census Tract Level (Continued)

Independent Variable	Dependent Variables							
	Total Commuting Time		High Income Group Commuting Time		Median Income Group Commuting Time		Low Income Group Commuting Time	
	Coef.	t	Coef.	t	Coef.	t	Coef.	T
% of Quaternary Industry	-0.513503	-1.60	-6.619151*	-8.48	-3.556617*	-8.46	-4.091197*	-13.35
% of Quinary Industry	-0.833609**	-2.23	-7.061623*	-7.95	-4.404481*	-9.34	-4.633163*	-13.06
% of Drive Alone	12.573940*	34.81	5.076468*	6.19	10.540710*	22.69	15.090370*	33.82
% of Carpool	27.022190*	58.14	16.203870*	14.05	23.090310*	37.04	30.839100*	55.57
% of Public Transportation	49.104600*	111.31	34.696050*	32.82	46.027870*	82.37	51.646890*	91.76
% of Bicycle and Walk	Dropped		Dropped		Dropped		Dropped	
% of Taxi, Others and Work at Home	0.319820	0.37	-15.266090*	-9.88	-0.629088	-0.63	2.497082*	2.86
% of 0 to 24 age	Dropped		Dropped		Dropped		Dropped	
% of 25 to 44 age	7.771348*	22.80	16.067130*	20.62	6.563806*	14.85	6.443218*	15.72
% of 45 to 64 age	4.594489*	11.84	12.541010*	13.86	3.177735*	6.10	5.315204*	10.73
% of 65 above	-1.987110*	-6.79	6.157267*	8.45	-1.864350*	-4.84	-3.248303*	-9.18
% of High school degree	Dropped		Dropped		Dropped		Dropped	
% of Bachelor degree	-4.101401*	-23.09	0.680066	1.51	-3.382199*	-14.75	-3.734603*	-18.43
% of Graduate degree	-13.059750*	-37.20	-20.452980*	-29.89	-17.416580*	-42.05	-15.806980*	-42.19
N	110,550		110,541		110,549		110,537	
F	(20,110529) = 5793.22		(20,110520) = 1518.20		(20,110528) = 3778.46		(20,110516) = 4216.74	
Prob > F	0.0000		0.0000		0.0000		0.0000	
R^2	0.5803		0.1982		0.4504		0.5083	

* : Coefficient is significant at the 0.01 level. **: Coefficient is significant at the 0.05 level.***: Coefficient is significant at the 0.1 level.
% of Primary Industry, % of Bicycle and Walk, % of 0 to 24 age, and % of High school degree are dropped as a reference category.

4.5 The Impacts of Urban Containment Policies on Urban Spatial Structure and Urban Commuting

The recursive system is designed to estimate the relationship between urban containment policies, urban sprawl, employment center formation, and urban commuting. As a result, this system can test *Hypothesis 2, 3, 4, and 5*. The first equation in the system is intended to test *Hypothesis 2 (the effect of urban containment policies on urban sprawl)* by analyzing the relationship between urban containment policies and urban sprawl. The second equation is intended to test *Hypothesis 3 (the effect of urban containment policies on employment centers)* by analyzing the effect of the predicted urban sprawl index on the number of employment centers. The third equation is intended to test *Hypothesis 4 (the effect of urban containment policies on commuting)* by analyzing the effects of the predicted urban sprawl index and the predicted number of employment centers on commuting time.

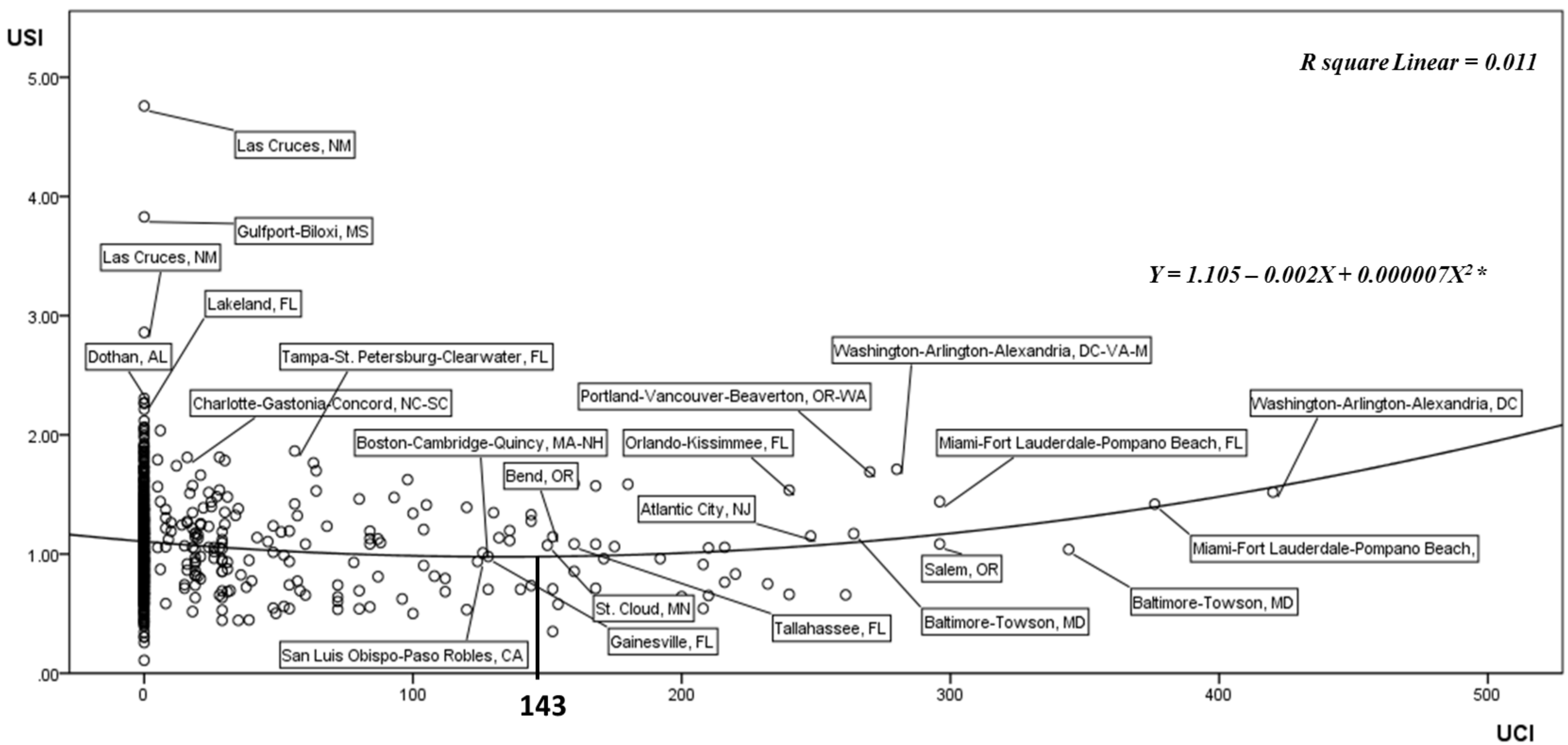
All regression equations are statistically significant by the *F*-test (p = .000), with R^2 of .13 (urban sprawl equation), .84 (employment center equation), and .62 (commuting time equation), respectively.

Table 15 shows the estimation results for the recursive system. In the first equation, all variables are significant at $\alpha < .01$. The negative sign of the UCI coefficient indicate that as the UCI increases, the USI decreases. This means that urban containment policies are estimated to significantly constrain urban sprawl. However, the positive sign of the UCI square coefficient reveals that the UCI has a curvilinear relationship with the USI. Figure 14 illustrates the curvilinear relationship between the USI and the UCI for the study MSAs. The estimated sprawl-minimizing value of the urban containment index is 143, and there are 39 MSA "observations" that reside beyond this point. These observations can be interpreted as examples of the unintended, or "excessive," effects of containment suggested by Brueckner (2000).

Three MSAs – Portland, Washington, DC, and Miami – are among those whose UCIs exceed the estimated sprawl-minimizing value. Research on two of the MSAs (Portland and Washington, DC) suggests that one basis for the outcome found in this dissertation is that these MSAs are multi-state entities, and that their growth containment policies are not uniformly applied throughout the metropolitan region. In the Washington, DC MSA, for example, the most restrictive containment policies are applied to the north in Montgomery County Maryland, while less restrictive policies prevail in the Virginia counties to the south. Pollakowsi and Wachter (1990) found that, as a result, housing prices grew faster in Montgomery than in the other MSA counties, and served to divert metropolitan growth to the south.

In the case of the Portland, the growth containment policies in the Oregon counties of the MSA are more restrictive than the concurrency policies applied in Clark County, across the Columbia River in Washington. Similar to the Washington DC MSA case, Jun (2006) found that the containment policy differential lead to a spillover of development across the river. Thus, in these two examples, it might be more appropriate to conclude that the principal underlying growth containment policy problem was a lack of uniformity.

The Miami MSA may represent the best example of excessive growth containment policy. In this case, the problem lies with Florida's concurrency regulations, which are intended to ensure that sufficient infrastructure capacity exists to serve new development. When infrastructure capacity limits are reached, the Florida concurrency program requires developers to cover the cost of expansion occasioned by their proposed developments. As Downs (2003) has argued, developers have a strong monetary incentive to avoid these infrastructure costs, and thus are drawn to locations (typically further out) where sufficient infrastructure capacity already exists.



* : Coefficient is significant at the 0.01 level. Each dot represents one metropolitan area.

Figure 14. Bivariate Regression Plots of the USI (Y) and the UCI (X)

The positive sign of the urbanized area coefficient indicates that as urbanized area increases, the USI increases. In contrast, the negative coefficient of population means that the USI decreases as metropolitan population increases. The coefficient (-0.17) of the time dummy indicates that the mean USI of 2010 is 16.8% lower than 2000's on average. The coefficient (-0.17) of the time dummy also represents a change from uncontrolled suburbanization to controlled suburbanization.

In the second equation estimating the number of employment centers, the coefficient (0.48) of the time dummy variable indicates that the estimated number of employment centers increased by 32.2% between 2000 and 2010. This reflects a continuing transformation from a monocentric to a polycentric spatial structure. The positive sign of the predicted USI indicates that as the predicted USI increases, the number of employment centers increases, supporting *hypothesis 3*. The coefficient (3.72) of the predicted USI indicates that if the predicted USI increases one unit, the number of employment centers increases by 3.72 centers, holding the other variables constant. That is, urban sprawl affects urban structure (i.e., employment center formation).

The total employment variable is statistically significant at $\alpha < .01$, indicating that additional jobs would increase the number of employment centers. Tertiary, quaternary, and quinary industry variables are also statistically significant. With respect to regional differences, only the Midwest dummy variable is statistically significant at $\alpha < .05$, indicating that the Midwest region has more employment centers relative to the Northeast region.

The third equation shows the estimated effects on commuting time. All variables are statistically significant except the over 65 age variable.

The time dummy variable estimates the average difference of commuting time between 2000 and 2010. The coefficient (1.37) of the time dummy indicates that the mean commuting time in 2010 is 1.37 minutes more than 2000, after controlling for the effects of the other variables.

The positive coefficient (3.92) of the predicted USI indicates that as the predicted USI increase one unit, commuting time increases 3.92 minutes, supporting the argument that sprawl contributes to longer commutes.

The predicted employment center variable coefficient shows that as the number of employment centers increase, commuting time also increases. In general, polycentric cities can reduce the costs of commuting when employees can locate near their jobs (Levinson and Kumar 1997). However, the result indicates that polycentric cities increase commuting time. It can thus be interpreted that commuting has become less important in the location choices of households as other factors have become more important, such as rapid job turnover and high moving costs, two-worker households, the increasing importance of non-work trips, and the increasing importance of amenities (Giuliano and Small, 1993). In addition, Banister (2012) explained the relationship between trip length, dispersal, and urban form based on Bertaud (2002). Figure 2 illustrated that the polycentric model with random movements has longer commuting distance (or time). That is, polycentric cities can increase commuting time through more complicated commuting patterns.

The results for other variables are similar to the results of the census tract level model except taxi, other and work at home, over 65 age, and graduate degree variables. The results of the JHR and JHR^2 variable also support *hypothesis 1*. The taxi, other and work-at-home variable coefficient is statistically significant at $\alpha < .01$, indicating that this mode is estimated to have longer commuting times relative to commuters who use bicycles and walk. The over age 65 variable coefficient is not statistically significant. The graduate degree variable coefficient is statistically significant at $\alpha < .05$ with a positive sign, indicating that a percent increase in graduate degrees increases estimated commuting time by 9.44 minutes.

Table 15. Regression Results for the Recursive Model

Independent Variable	Dependent Variables					
	Urban Sprawl Index		Number of Employment Centers		Total Commuting Time	
	Coef.	T	Coef.	t	Coef.	t
Constant	1.1129200*	51.21	-8.016883*	-4.23	-30.276350*	-4.95
Urban Containment Index	-0.0017949*	-3.67				
Urban Containment Index^2	0.0000059*	3.48				
Urbanized Area	0.0000009*	7.49				
Population	-0.0000001*	-5.59				
Time Dummy	-0.1656425*	-5.62	0.479208**	2.25	1.364693*	3.67
Predicted Urban Sprawl Index			3.724865*	3.06	3.918049*	5.18
Total Jobs			0.000005*	3.85		
GDP			-0.000011	-1.36		
% of Primary Industry			Dropped			
% of Secondary Industry			2.132653	1.43		
% of Tertiary Industry			3.437199**	1.98		
% of Quaternary Industry			5.106108*	3.28		
% of Quinary Industry			4.858219**	2.28		
Northeast			Dropped			
Midwest			0.271007**	2.00		
South			0.176242	1.43		
West			0.287498	1.58		
Predicted Employment Centers					0.273395*	5.47

Table 15. Regression Results for the Recursive Model (Continued)

Independent Variable	Dependent Variables					
	Urban Sprawl Index		Number of Employment Centers		Total Commuting Time	
	Coef.	T	Coef.	t	Coef.	t
Total JHR					-3.109866*	-3.81
Total JHR^2					0.264923**	2.20
Population Density					-0.000005*	-2.89
Median Income					0.000089*	6.22
% of Drive Alone					35.936690*	5.58
% of Carpool					71.898200*	9.09
% of Public Transportation					63.710250*	6.14
% of Bicycle and Walk					Dropped	
% of Taxi, Others and Work at Home					30.952540*	2.78
% of 0 to 24 age					Dropped	
% of 25 to 44 age					20.529440*	3.39
% of 45 to 64 age					17.455290*	3.28
% of 65 above					4.411587	0.88
% of High school degree					Dropped	
% of Bachelor degree					-8.532791*	-5.24
% of Graduate degree					9.442932**	2.53
N	700		700		700	
F	(5, 694) = 24.98		(11, 688) = 63.54		(16, 683) = 133.18	
Prob > F	0.0000		0.0000		0.0000	
R^2	0.1282		0.8411		0.6223	

*: Coefficient is significant at the 0.01 level. **: Coefficient is significant at the 0.05 level.***: Coefficient is significant at the 0.1 level.
% of Primary Industry, Northeast,% of Bicycle and Walk, % of 0 to 24 age, and % of High school degree are dropped as a reference category.

The fourth equation is also estimated to test *hypothesis 5 (the effect of urban containment policies on commuting of different income groups)* by analyzing the effects of the predicted USI and the predicted number of employment centers on the commuting time of different income levels. Table 16 shows regression results for each income group.

Each equation is statistically significant in terms of the *F*-test (p = .000), and shows fair goodness of fit, as indicated by R^2, .53 (high income model), .53 (median income model), and .62 (low income model), respectively. Most variables in all equations are statistically significant, except JHR^2 in the low income equation, population density in the median income equation, age 25 to 44 in the high income equation and over age 65 variables in high and median income equation, which are not statistically significant.

The predicted employment center and predicted USI variables in all equations are statistically significant at $\alpha < .01$ with the positive sign, indicating that as the predicted number of employment centers and the predicted USI increase, commuting time also increases. With an increase of one employment center, the estimated mean commuting time increased by 0.21 minutes (high income group), 0.27 minutes (median income group), and 0.30 minutes (low income group), respectively. That is, an increase in the incidence of employment centers increases the estimated commuting time of the low income group more than that of the other income groups. Also, if the predicted USI increases one unit, estimated commuting time increases 5.49 minutes (high income group), 4.39 minutes (median income group), and 2.13 minutes (low income group), respectively.

The JHR and JHR^2 variable are statistically significant at $\alpha < .01$, except JHR^2 in the low income equation. Consistent with the bivariate and census tract level regressions, the slope coefficients of the JHR and JHR^2 in all equations are positive and negative, respectively. These signs indicate a curvilinear relationship supporting *hypothesis 1*. In addition, the slope coefficients of the JHR (-17.45) and JHR^2 (0.79) in high income equation are the steepest among the income level equations. In contrast with high income group, the slope coefficient of the JHR (-0.31) and JHR^2 (0.00008) in low income model is almost flat. These results also support the functional relationship between commuting time and J-H ratio of different income groups illustrated in Figure 7.

The time dummy variable coefficients for all equations are statistically significant at $\alpha < .01$. The positive coefficients for the median and low income groups represent increases in average commuting time of 1.09 minutes (median income group) and 1.53 minutes (low income group), respectively, between 2000 and 2010. However, the negative coefficient (-2.51) of the high income group indicates a decrease in average commuting time by 2.51 minutes between 2000 and 2010.

The population density variable coefficients in all equations are also statistically significant at $\alpha < .01$. The negative coefficients of the median and low income equation indicate that people residing in denser areas are more likely to commute for work located closer to their residence. In contrast, the coefficient of the high income group is positive, indicating that these people are more likely to commute for work to remoter areas.

These results suggest that the commuting time of high income groups with lower J-H ratios can be more responsive to a decrease in employment opportunities and the commuting time of low income groups with higher J-H ratios can be more responsive to an increase in employment opportunities.

The estimated results for the other variables are similar to the results of total commuting time equation. In the case of the median income variable, the results indicate that as median income increases, commuting time for all income groups increase. Transportation mode variables represent that people who choose the bicycles and walk mode in all income groups have shorter commuting times relative to the other transportation modes, and the youngest cohort in all income groups also have shorter commuting times relative to the other age groups. Educational attainment variables in all equations are statistically significant. The people with a high school degree, as the reference category in all equations, have relatively longer commuting times than people with bachelor degrees. The people with graduate degree in all equations have the longest estimated commuting times.

Table 16. Regression Results for Commuting Time of Different Income Groups

Independent Variable	Dependent Variables					
	High Income Group Commuting Time		Median Income Group Commuting Time		Low Income Group Commuting Time	
	Coef.	T	Coef.	T	Coef.	t
Constant	-46.990650*	-4.47	-27.345640*	-3.54	-29.925940*	-5.85
Predicted Employment Centers	0.210560*	2.92	0.273829*	4.09	0.299473*	7.60
Predicted Urban Sprawl Index	5.489819*	4.90	4.393995*	4.77	2.128588*	3.55
JHR (Each Income Group)	-17.444860*	-6.12	-3.513453*	-3.54	-0.307052*	-3.15
JHR^2 (Each Income Group)	0.794018*	5.72	0.179430*	3.03	0.000828	1.14
Time Dummy	-2.512807*	-3.81	1.088975*	2.58	1.528734*	4.38
Population Density	0.000014*	4.65	-0.000002	-0.89	-0.000013*	-7.11
Median Income	0.000267*	11.72	0.000127*	6.29	0.000040**	2.09
% of Drive Alone	43.326600*	4.07	32.876560*	4.24	33.711610*	6.08
% of Carpool	88.704860*	7.06	65.117760*	6.86	71.846910*	10.79
% of Public Transportation	77.253790*	4.98	60.338870*	4.46	54.256420*	6.69
% of Bicycle and Walk	Dropped		Dropped		Dropped	
% of Taxi, Others and Work at Home	44.418030**	2.48	23.399690***	1.74	34.749730*	3.66
% of 0 to 24 age	Dropped		Dropped		Dropped	
% of 25 to 44 age	4.096548	0.41	20.182630*	2.74	26.928510*	5.00
% of 45 to 64 age	49.611560*	6.06	19.852160*	3.14	12.419950*	2.79
% of 65 above	-12.018100	-1.56	3.302972	0.57	9.709681**	2.28
% of High school degree	Dropped		Dropped		Dropped	
% of Bachelor degree	-10.165490*	-3.74	-9.235015*	-4.54	-7.101049*	-5.85
% of Graduate degree	13.066970**	2.24	8.652252***	1.73	8.916032*	2.90
N	700		700		700	
F	(16, 683) = 92.71		(16, 683) = 100.81		(16, 683) = 134.94	
Prob > F	0.0000		0.0000		0.0000	
R^2	0.5271		0.5249		0.6218	

*: Coefficient is significant at the 0.01 level. **: Coefficient is significant at the 0.05 level.
***: Coefficient is significant at the 0.1 level.
% of Bicycle and Walk, % of 0 to 24 age, and % of High school degree are dropped as a reference category.

Overall, the effects of urban containment policies on urban commuting can be well explained by the recursive system, which is structured to reflect a maintained hierarchy. The first equation estimating the effect of urban containment policies on urban sprawl indicates that urban containment policies can reduce urban sprawl.

In the second equation, predicted urban sprawl increased the number of employment centers. If urban sprawl is controlled by urban containment policies, the number of employment centers can thus be affected by urban containment policies.

In the third equation, predicted urban sprawl and the predicted number of employment centers increased urban commuting times. If both variables are controlled by urban containment policies, then urban commuting time can be affected by both controlled variables, which, in turn, are influenced by urban containment policies. This means that commuting time can be influenced by urban containment policies. Figure 15 illustrates the recursive system and its effects.

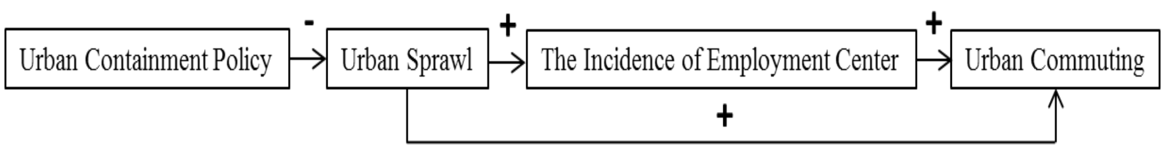


Figure 15. Recursive System Estimates of the Effect of Urban Containment Policies on Urban Commuting

4.6 The Impacts of Urban Containment Policies on Density and Housing Values

Two regression models are estimated to test *hypothesis 6 (the effect of urban containment policies on density).* In addition, one regression model is added to estimate the effect of urban containment policies on housing values.

Table 17 shows the results of the three regression models. All regression models are statistically significant by the F-test (p = .000) and showed R^2 of .53 (population density model), .50 (employment density model), and .55 (median housing value model), respectively.

The UCI variables in the population and the employment density model are statistically significant at $\alpha < .01$ and .05, respectively, with positive signs, indicating that as the UCI increases, population and employment density also increase. Figure 16 shows the relationship between the level of urban containment policy and density, indicating that the stronger urban containment policy, the more density is increased. These results are similar to previous studies (Rodriguez et al. 2006; Wassmer, 2006; Woo and Guldmann 2011; Geshkov and DeSalvo, 2012).

The negative coefficients of the time dummy variable in the population and the employment density model represents a decrease in population and employment density between 2000 and 2010, with statistical significance at $\alpha < .01$ and .05, respectively.

The GDP variables in both models are statistically significant at $\alpha < .01$ with positive signs. This means that regions with higher level of economic activity also have higher density.

The regional dummy variable coefficients in both models are statistically significant. The Northeast variable in both models, as a reference category, has relatively higher estimated density than the other regions. In addition, the estimated density of the South region in both models is relatively lower than other regions.

Only the quaternary industry variable in the employment density model is statistically significant at $\alpha < .01$ with the positive sign, indicating that an additional percentage of quaternary industry share increased employment density by 7.08.

All variables in median housing values model are statistically significant at $\alpha < .01$ except the urbanized area variable, which is not significant.

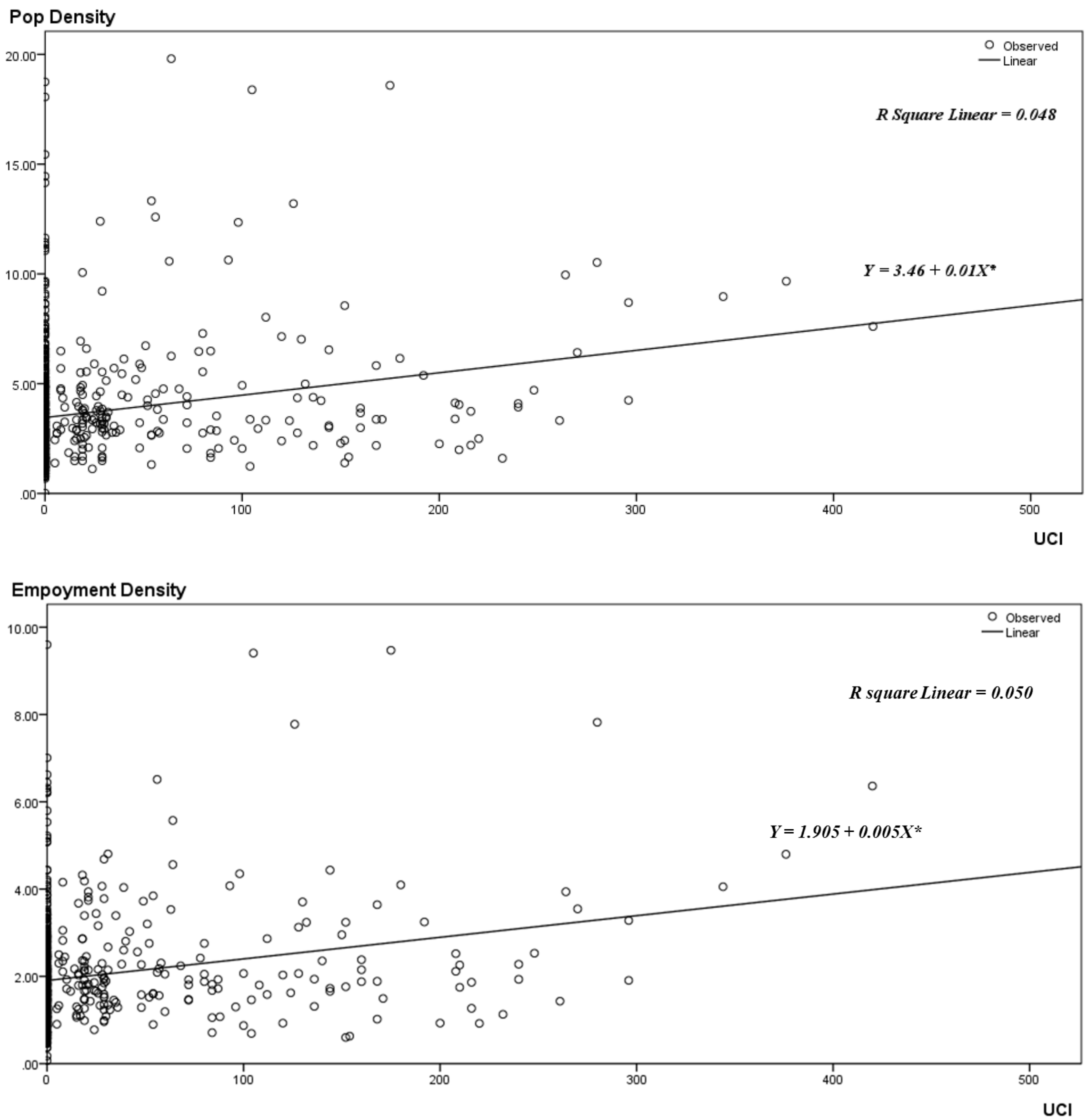
The positive coefficient (347.04) of the UCI indicates that as the UCI increases one unit, estimated median housing values increase 347.04 dollars, likely because urban containment policies limit the supply of land.

The positive coefficient (65231.42) of the time dummy variable represents an estimated increase in median housing values of 65,231.42 dollars between 2000 and 2010. Greater population density decreases estimated housing price, while GDP increases housing price. In addition, the estimated housing price in the West region is the highest and the estimated housing price in the South region is the lowest.

Table 17. Regression Results for Density and Housing Values

Independent Variable	Dependent Variables					
	Population Density		Employment Density		Median Housing Value	
	Coef.	t	Coef.	t	Coef.	t
Constant	4.391825*	17.90	-1.612793	-1.13	114326.5*	15.30
Urban Containment Index	0.003457**	2.19	0.002435*	3.71	347.04*	7.17
Time dummy	-0.338496**	-2.47	-0.371400*	-5.35	65231.42*	15.40
Population Density					-0.21*	-5.77
GDP	0.000023*	15.33	0.000009*	10.10	0.27*	2.92
Urbanized Area					-0.012	-0.48
Northeast	Dropped		Dropped		Dropped	
Midwest	-1.242095*	-5.00	-0.414566*	-3.25	-42342.8*	-5.24
South	-2.224129*	-8.98	-1.022061*	-8.42	-44660.1*	-5.50
West	-0.535194***	-1.87	-0.643872*	-4.30	37567.5*	3.60
% of Primary Industry			Dropped			
% of Secondary Industry			1.868864	1.31		
% of Tertiary Industry			2.289322	1.35		
% of Quaternary Industry			7.077516*	4.71		
% of Quinary Industry			1.639374	0.88		
N	690		693		700	
F	(6, 683) = 72.10		(10, 682) = 36.47		(8, 691) = 218.62	
Prob > F	0.0000		0.0000		0.0000	
R^2	0.5319		0.5036		0.5470	

*: Coefficient is significant at the 0.01 level. **: Coefficient is significant at the 0.05 level.
***: Coefficient is significant at the 0.1 level.
Northeast and % of Primary Industry are dropped as a reference category.
In the case of the population density and employment density models, 10 and 7 observations are excluded, respectively, because of extreme outliers.



* : Coefficient is significant at the 0.01 level. Each dot represents one metropolitan area.

Figure16. Bivariate Regression Plots of Population and Employment Density (Y) and the UCI (X)

CHAPTER V

CONCLUSION

5.1 Summary

This dissertation was designed to better understand metropolitan development patterns and the effects of urban containment polices on commuting patterns in the U.S. metropolitan areas. Previous studies have focused on the impacts of urban containment policies on urban size, spatial structure, residential segregation and housing prices, often using only one or a limited number of study areas. Although some studies have analyzed the relationship between urban containment policies and urban commuting, the policies were often not well represented. In addition, little work has examined the interrelationship of urban containment policies, urban form, and commuting patterns of different income groups in U.S. metropolitan areas, and studies related to urban containment policies often did not consider the levels of urban containment policy. Thus, this dissertation started with two objectives: (1) to analyze the effects of urban containment policy on urban form, spatial structure, and commuting; and (2) to determine whether there is a level of growth containment policy intervention that balances the positive and negative urban form, spatial structure, and commuting consequences.

This dissertation used data from 350 metropolitan areas to explore the effects of urban containment polices on commuting patterns with several important indexes and variables. The USI was constructed by the operationalization of the central tendency and dispersion of the J-H ratio in relation to commuting time. In addition, the UCI was calculated based on Wassmer's (2006) study. The number of employment centers was calculated using the LISA model and cutoff point method employed in previous research.

The results of this dissertation confirmed that the relationship between the J-H ratio and commuting time is curvilinear for all MSAs, extending the findings of previous research (Peng1997, Park and Kwon 2009). In addition, this dissertation found the relationship between the type of J-H imbalance and metropolitan size by employing the Weitz (2003) J-H imbalance typology and J-H ratio and commuting time of each income group in metropolitan areas.

This dissertation used a recursive equation system because the relationships among urban containment policies, urban sprawl, employment center formation, and urban commuting are hierarchical and complex. The results indicated that urban containment policies affect urban sprawl, which, in turn, affects the number of employment centers. Urban sprawl and employment center formation then were found to affect urban commuting.

Finally, this dissertation has estimated the relationship between urban containment policies and density, finding that as the levels of urban containment policy increase, population and employment density also increase. In addition, this research examined the effects of urban containment policies on housing values, finding that as the levels of urban containment policy increase, housing values also increase. These results are consistent the findings of the previous studies.

5.2 Conclusion and Policy Implications

This dissertation started with contrasting views (planning-oriented vs. market-oriented) of urban sprawl and urban containment policies. Planning-oriented scholars asserted the problems of '*geographic sprawl* (GS)' and the positive effects of urban containment polices, while market-oriented scholars asserted the problems of '*economic sprawl* (ES)' and the negative or negligible effects of urban containment policies. Therefore, this dissertation analyzed whether urban containment policies affect urban sprawl, employment center formation, and urban commuting with six hypotheses to test the contrasting views. In addition, this study has examined the effects of urban containment policy comprehensively across all U.S MSAs, which allowed a determination of the level where such policy produced the maximum benefit in limiting sprawl. Lastly, a recursive model consistent with urban development theory was developed and estimated, providing insights on selected aspects of the urban development process.

To test the first hypothesis, this research analyzed the relationship between the J-H ratio and commuting time. The relationship was found to be curvilinear, supporting a trade-off of the opportunity cost of commuting and employment opportunities. This result indicates the importance of the J-H balance on commuting time. In addition, this dissertation classified the relationship between the type of J-H imbalance and metropolitan size. This classification can contribute to solutions regarding J-H imbalance depending on the features of a metropolitan area. Type 1 (low income group) and type 2 (high income group) J-H imbalance may occur in large metropolitan areas, while type 3 (low income group) and type 4 (high income group) J-H imbalance may occur in small metropolitan areas. Therefore, the J-H policy for high income groups in large metropolitan areas should focus on the additional supply of housing for high-wage workers in downtown employment centers. The preferred method for low income groups in large metropolitan areas is to supply more housing for low-wage workers in suburban employment centers (or edge cities), while the preferred method for low income groups in small metropolitan areas is to promote more employment opportunities for lower-wage workers in older suburbs and central-city neighborhoods.

To test the second hypothesis, this research analyzed the effect of urban containment policies on urban sprawl. The results found a curvilinear relationship, indicating that moderate urban containment policies decrease urban sprawl, while “excessive” urban containment policies can increase urban sprawl. This suggests that moderate urban containment policies can control ‘*geographic sprawl* (GS)’, but stronger urban containment policies can worsen ‘*economic sprawl* (ES)’. Therefore, this result helps to relate the contrasting views (planning-oriented vs. market-oriented) of urban sprawl and urban containment policies.

The second regression equation in the recursive model (Table 15) was estimated to test the third hypothesis, the effect of urban containment policies on employment center formation. The predicted USI was found to positively affect the number of employment centers. Because the predicted USI was affected by the UCI, it can be concluded that urban containment policies can affect the incidence of employment centers by controlling urban sprawl.

Hypothesis 4 and *Hypothesis 5* test the effect of urban containment policies on urban commuting. The third equation in the recursive model provides a test of these hypotheses (Table 15 and 16). The results indicate that the predicted number of employment centers and the predicted USI in all equations are estimated to increase urban commuting time. In general, market-oriented scholars have asserted that polycentric cities can reduce the costs of commuting (Gordon et al., 1991; Levinson and Kumar 1997). However, these results indicate that polycentric structures increase commuting time. Banister (2012) explained that polycentric cities with random movements can experience longer commuting distances (or times) because of complex commuting patterns, the city's characteristics, and socio demographic factors. In addition, the incidence of employment centers increases the commuting time of low income groups more than that of the other income groups.

In the case of the predicted USI, however, an increase adds more to the commuting time of high income groups than to that of the other income groups. This means that people with high income in a sprawling region live relatively farther from their work places than people from the other income groups. Both variables are predicted by urban containment policies. Therefore, urban containment policies can affect urban commuting by controlling urban sprawl and the incidence of employment centers.

Previous studies (Rodriguez et al. 2006; Wassmer, 2006; Woo and Guldmann 2011; Geshkov and DeSalvo, 2012) have found that urban containment policies increase population or employment density. Therefore, analysis was conducted to analyze the effect of urban containment policies on density (i.e., *hypothesis 6*). The results supported the findings of the previous studies. That is, the urban containment policies promote higher density urbanization.

Some studies (Richardson and Gordon, 2000; O'Toole, 2007) have cited an increase in housing prices as a negative effect of urban containment policies. To address this effect, this research analyzed the relationship between urban containment policies and housing values. The results indicate that as urban containment policies increase, housing values also increase, likely because urban containment policies limit the supply of land (Hall, 1997).

The results of this dissertation indicate that urban containment policies play an important role in affecting urban sprawl, employment center formation, and urban commuting, as well as reconciling contrasting views (planning-oriented vs. market-oriented) of urban containment policies.

Implementing urban containment policies can produce positive effects such as more compact development, which, in turn, can also promote J-H balance. However, as seen in the relationship between urban containment policies, urban sprawl and housing values, stronger urban containment policies can produce negative effects as well, such as traffic congestion and an increase in housing prices.

The results of this research generalize the discussion of urban containment policies from previous literatures because it uses data covering all metropolitan areas in the U.S. However, this dissertation has several limitations in terms of the time periods studied and the variables employed.

First, this dissertation did not include 1990 data because there are problems such as missing variables (i.e., commuting times for each income level, educational attainment, and Gross Domestic Product), and problems with 1990 CTPP data[12]. If the 1990 data were added to this dissertation, the results might have been different and more dynamic.

Second, the analyses in this dissertation were conducted under the assumption that other factors (e.g., environmental benefits, amenities, planning expenditures, public transportation services, transport system, transit, roadway capacity and congestion and some unobserved variables that comprise the unexplained part of the model) are held constant or are uncorrelated with the model variables. In addition, some studies (Nelson et al., 2004; Brueckner and Largey, 2008) analyzed the relationship between urban containment policies (or urban sprawl) and social integration. Therefore, if the social integration variables such as index of spatial proximity, isolation index, interaction index, and diversity index are added, the effect of urban containment policies on social integration could be analyzed.

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12 Many areas do not have geographic maps, thus, this data cannot be matched.

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APPENDIX. Number of Employment Centers and Values of the Indexes in 2000 and 2010

MSA	EMCE00	EMCE10	UCI00	UCI10	USI00	USI10
New York-Northern New Jersey-Long Island, NY-NJ-PA	30	28	0	0	1.17	1.14
Los Angeles-Long Beach-Santa Ana, CA	15	14	0	0	1.04	1.05
Chicago-Naperville-Joliet, IL-IN-WI	13	14	0	0	1.31	1.29
Philadelphia-Camden-Wilmington, PA-NJ-DE	7	5	0	0	0.94	0.96
Dallas-Fort Worth-Arlington, TX	7	11	0	0	2.02	1.73
Miami-Fort Lauderdale-Pompano Beach, FL	7	10	296	376	1.44	1.42
Washington-Arlington-Alexandria, DC-VA-MD-WV	11	13	280	420	1.71	1.52
Houston-Sugar Land-Baytown, TX	11	5	0	0	1.73	1.69
Detroit-Warren-Livonia, MI	12	13	0	0	1.30	1.17
Boston-Cambridge-Quincy, MA-NH	7	9	56	126	1.42	1.01
Atlanta-Sandy Springs-Marietta, GA	10	13	0	0	2.06	1.85
San Francisco-Oakland-Fremont, CA	2	4	105	175	1.41	1.06
Riverside-San Bernardino-Ontario, CA	6	6	54	84	0.94	1.19
Phoenix-Mesa-Scottsdale, AZ	11	14	0	0	1.92	1.46
Seattle-Tacoma-Bellevue, WA	8	9	64	144	1.53	1.33
Minneapolis-St. Paul-Bloomington, MN-WI	7	10	25	35	1.40	1.38
San Diego-Carlsbad-San Marcos, CA	5	5	63	93	1.76	1.47
St. Louis, MO-IL	10	8	0	0	1.61	1.61
Baltimore-Towson, MD	8	6	264	344	1.17	1.04
Pittsburgh, PA	5	3	0	0	1.62	1.24
Tampa-St. Petersburg-Clearwater, FL	6	5	56	136	1.86	1.20
Denver-Aurora, CO	8	8	30	130	1.78	1.35
Cleveland-Elyria-Mentor, OH	2	1	0	0	1.00	1.15
Cincinnati-Middletown, OH-KY-IN	4	4	0	0	1.36	1.22
Portland-Vancouver-Beaverton, OR-WA	6	6	180	270	1.59	1.69
Kansas City, MO-KS	6	6	0	0	1.37	1.20
Sacramento--Arden-Arcade--Roseville, CA	5	6	21	51	1.66	1.18
San Jose-Sunnyvale-Santa Clara, CA	2	3	28	98	1.81	1.62
San Antonio, TX	5	6	0	0	1.24	1.34
Orlando-Kissimmee, FL	8	5	160	240	1.59	1.54
Columbus, OH	4	3	0	0	1.55	1.25
Providence-New Bedford-Fall River, RI-MA	2	2	0	0	0.88	0.59
Virginia Beach-Norfolk-Newport News, VA-NC	0	4	21	31	1.26	0.87
Indianapolis-Carmel, IN	5	5	0	0	1.56	1.67
Milwaukee-Waukesha-West Allis, WI	5	2	19	29	0.74	0.85
Las Vegas-Paradise, NV	1	2	0	0	1.28	1.71
Charlotte-Gastonia-Concord, NC-SC	5	5	6	16	2.04	1.81
New Orleans-Metairie-Kenner, LA	1	1	0	0	0.94	1.02
Nashville-Davidson--Murfreesboro--Franklin, TN	4	3	0	0	1.81	1.80
Austin-Round Rock, TX	4	6	0	0	1.30	1.19
Memphis, TN-MS-AR	4	5	0	0	1.45	1.20
Buffalo-Niagara Falls, NY	2	2	0	0	0.75	0.72
Louisville-Jefferson County, KY-IN	5	5	0	0	1.64	1.52
Hartford-West Hartford-East Hartford, CT	3	2	0	0	1.29	1.14
Jacksonville, FL	3	4	64	144	1.70	1.28

MSA	EMCE00	EMCE10	UCI00	UCI10	USI00	USI10
Richmond, VA	2	3	0	0	1.31	1.12
Oklahoma City, OK	5	4	0	0	1.29	1.41
Birmingham-Hoover, AL	2	3	0	0	1.98	1.74
Rochester, NY	1	1	0	0	1.00	0.96
Salt Lake City, UT	1	3	0	0	1.90	1.46
Bridgeport-Stamford-Norwalk, CT	3	3	0	0	0.67	0.70
Tulsa, OK	6	5	0	0	1.57	1.39
Dayton, OH	2	1	16	26	1.26	1.06
Tucson, AZ	5	5	28	68	1.54	1.23
Albany-Schenectady-Troy, NY	3	4	0	0	1.57	1.40
New Haven-Milford, CT	1	2	0	0	0.86	0.77
Fresno, CA	1	1	48	78	1.02	0.93
Raleigh-Cary, NC	1	4	14	24	1.24	1.23
Omaha-Council Bluffs, NE-IA	4	4	0	0	1.38	1.19
Oxnard-Thousand Oaks-Ventura, CA	0	0	0	0	1.02	0.66
Worcester, MA	3	3	0	0	0.97	1.07
Grand Rapids-Wyoming, MI	2	2	0	0	1.24	0.99
Allentown-Bethlehem-Easton, PA-NJ	2	1	0	0	1.04	1.01
Albuquerque, NM	4	4	26	46	0.97	1.10
Baton Rouge, LA	4	3	0	0	1.43	1.45
Akron, OH	0	0	0	0	1.17	0.99
Springfield, MA	0	3	0	0	0.72	0.66
El Paso, TX	2	3	0	0	1.48	1.62
Bakersfield, CA	2	2	0	0	0.50	1.83
Toledo, OH	1	1	0	0	0.80	0.68
Syracuse, NY	2	2	0	0	1.36	1.01
Columbia, SC	4	2	0	0	1.38	1.19
Greensboro-High Point, NC	1	3	0	0	1.29	1.05
Knoxville, TN	3	1	18	48	1.57	1.24
Little Rock-North Little Rock-Conway, AR	3	1	12	22	1.74	1.39
Youngstown-Warren-Boardman, OH-PA	1	0	0	0	0.82	0.72
Sarasota-Bradenton-Venice, FL	2	1	171	261	0.96	0.66
Wichita, KS	0	0	10	20	1.26	1.16
McAllen-Edinburg-Mission, TX	1	2	0	0	1.50	1.03
Stockton, CA	1	1	0	0	0.72	0.64
Scranton--Wilkes-Barre, PA	1	1	0	0	1.16	0.88
Greenville-Mauldin-Easley, SC	2	4	0	0	1.30	1.17
Charleston-North Charleston, SC	1	2	6	16	0.87	0.92
Colorado Springs, CO	0	0	0	0	1.02	0.82
Harrisburg-Carlisle, PA	2	1	0	0	1.11	0.96
Madison, WI	1	3	19	29	0.97	0.94
Augusta-Richmond County, GA-SC	2	0	0	0	1.10	0.99
Jackson, MS	1	1	0	0	1.36	1.27
Portland-South Portland-Biddeford, ME	3	2	0	0	1.21	0.96
Lakeland, FL	1	2	0	0	2.27	1.13
Des Moines-West Des Moines, IA	1	1	0	0	1.28	1.06
Chattanooga, TN-GA	2	2	0	0	1.85	1.38
Palm Bay-Melbourne-Titusville, FL	1	1	120	220	1.39	0.83
Lancaster, PA	0	1	8	18	1.37	1.21
Boise City-Nampa, ID	2	1	0	0	1.25	1.34

MSA	EMCE00	EMCE10	UCI00	UCI10	USI00	USI10
Santa Rosa-Petaluma, CA	1	1	60	100	0.66	0.50
Lansing-East Lansing, MI	2	3	0	0	1.10	0.92
Modesto, CA	0	0	8	18	0.58	0.52
Deltona-Daytona Beach-Ormond Beach, FL	1	2	0	0	0.95	1.06
Ogden-Clearfield, UT	1	0	0	0	1.46	1.68
Cape Coral-Fort Myers, FL	1	2	88	168	1.10	1.08
Flint, MI	1	1	0	0	1.90	1.03
Durham, NC	0	3	0	0	1.34	1.17
Winston-Salem, NC	2	2	0	0	1.60	1.41
Spokane, WA	1	1	9	39	1.12	0.95
Pensacola-Ferry Pass-Brent, FL	1	2	0	0	1.25	0.94
Lexington-Fayette, KY	2	1	42	52	1.14	0.99
Canton-Massillon, OH	1	3	0	0	1.09	0.92
Corpus Christi, TX	2	2	0	0	1.91	1.13
Salinas, CA	1	1	0	0	0.70	0.59
Mobile, AL	0	0	0	0	1.43	1.21
Santa Barbara-Santa Maria-Goleta, CA	1	0	112	152	0.80	0.35
Vallejo-Fairfield, CA	0	0	80	120	0.69	0.53
Fort Wayne, IN	2	1	0	0	1.28	0.87
Beaumont-Port Arthur, TX	1	0	0	0	0.94	0.80
York-Hanover, PA	0	0	8	18	1.22	1.06
Manchester-Nashua, NH	0	1	0	0	0.76	0.62
Provo-Orem, UT	2	1	0	0	0.63	0.78
Davenport-Moline-Rock Island, IA-IL	0	0	0	0	0.91	0.84
Shreveport-Bossier City, LA	2	1	0	0	1.21	0.92
Reading, PA	0	0	0	0	1.20	0.92
Asheville, NC	2	1	0	0	2.26	0.79
Springfield, MO	3	3	0	0	1.40	1.41
Visalia-Porterville, CA	0	0	52	72	0.56	0.60
Peoria, IL	2	2	0	0	1.38	1.18
Trenton-Ewing, NJ	2	2	0	0	0.68	0.53
Salem, OR	0	0	216	296	1.06	1.08
Fayetteville-Springdale-Rogers, AR-MO	1	1	0	0	1.07	1.10
Montgomery, AL	1	1	0	0	1.22	1.25
Reno-Sparks, NV	1	2	0	0	1.03	0.76
Evansville, IN-KY	2	2	0	0	1.30	1.04
Huntsville, AL	1	1	0	0	1.22	1.21
Hickory-Lenoir-Morganton, NC	1	1	0	0	1.61	1.43
Fayetteville, NC	0	1	5	15	1.79	1.07
Brownsville-Harlingen, TX	0	0	0	0	1.26	0.82
Killeen-Temple-Fort Hood, TX	0	0	0	0	1.80	1.08
Eugene-Springfield, OR	2	1	160	240	0.85	0.66
Ann Arbor, MI	2	1	0	0	0.68	0.86
Tallahassee, FL	1	1	80	160	1.46	1.08
Rockford, IL	0	0	0	0	0.95	0.63
Port St. Lucie, FL	0	1	100	200	1.34	0.64
South Bend-Mishawaka, IN-MI	1	1	0	0	1.07	0.82
Kalamazoo-Portage, MI	2	1	10	20	1.19	0.81
Charleston, WV	1	1	0	0	1.29	1.34
Utica-Rome, NY	0	1	0	0	1.12	0.79

MSA	EMCE00	EMCE10	UCI00	UCI10	USI00	USI10
Savannah, GA	1	1	0	0	1.06	1.02
Huntington-Ashland, WV-KY-OH	0	0	0	0	0.77	0.75
Roanoke, VA	2	2	0	0	1.15	1.27
Green Bay, WI	1	1	19	29	0.82	0.64
Columbus, GA-AL	1	0	0	0	0.77	0.67
Erie, PA	0	0	0	0	1.25	0.80
Duluth, MN-WI	0	2	0	0	0.94	0.77
Wilmington, NC	0	1	19	29	0.92	0.69
Fort Smith, AR-OK	1	0	0	0	1.87	1.58
Boulder, CO	1	1	132	192	1.14	0.96
Lincoln, NE	1	1	39	49	0.45	0.50
Norwich-New London, CT	1	1	0	0	1.13	0.82
Ocala, FL	1	1	24	104	1.52	1.21
Santa Cruz-Watsonville, CA	1	1	40	80	0.77	0.54
Spartanburg, SC	0	1	0	0	1.28	1.31
Atlantic City, NJ	2	2	168	248	1.57	1.15
Binghamton, NY	1	0	0	0	1.13	0.84
Fort Collins-Loveland, CO	0	0	140	210	0.70	0.65
Naples-Marco Island, FL	1	1	54	144	0.74	0.73
Lubbock, TX	0	1	0	0	1.13	0.79
San Luis Obispo-Paso Robles, CA	1	1	84	124	1.08	0.94
Gulfport-Biloxi, MS	0	0	0	0	0.70	3.83
Lafayette, LA	2	2	0	0	1.17	0.86
Cedar Rapids, IA	1	1	0	0	1.13	1.01
Gainesville, FL	1	1	128	208	0.98	0.91
Clarksville, TN-KY	0	0	5	15	1.56	0.74
Bremerton-Silverdale, WA	0	0	16	96	0.87	0.62
Kingsport-Bristol-Bristol, TN-VA	0	0	0	0	1.34	1.07
Lynchburg, VA	0	0	0	0	1.20	0.99
Amarillo, TX	0	0	0	0	1.17	0.64
Topeka, KS	0	0	0	0	1.31	1.23
Hagerstown-Martinsburg, MD-WV	1	0	34	54	1.32	1.19
Yakima, WA	1	0	24	104	1.06	0.90
Macon, GA	1	0	0	0	1.78	1.45
Barnstable Town, MA	1	0	0	0	0.67	0.70
Waco, TX	0	1	0	0	1.08	0.73
Merced, CA	0	1	32	72	0.69	0.54
Champaign-Urbana, IL	1	2	0	0	1.12	0.95
Saginaw-Saginaw Township North, MI	0	0	0	0	1.07	0.93
Olympia, WA	1	2	136	216	1.11	0.76
Chico, CA	0	1	72	112	0.74	0.68
Appleton, WI	0	0	19	29	0.94	1.05
Springfield, IL	1	1	16	26	1.27	1.02
Burlington-South Burlington, VT	1	2	0	0	1.14	0.86
Myrtle Beach-Conway-North Myrtle Beach, SC	1	1	0	0	1.38	0.94
Houma-Bayou Cane-Thibodaux, LA	0	0	0	0	1.04	0.83
Longview, TX	0	0	0	0	2.12	1.51
Lake Charles, LA	0	0	0	0	1.13	0.66
Florence, SC	1	1	0	0	1.18	0.85
Laredo, TX	0	0	0	0	0.83	0.57

MSA	EMCE00	EMCE10	UCI00	UCI10	USI00	USI10
Tuscaloosa, AL	1	0	0	0	1.17	1.00
Kennewick-Richland-Pasco, WA	0	0	6	36	1.44	0.82
Racine, WI	0	0	19	29	0.63	0.44
Sioux Falls, SD	0	1	20	30	1.13	1.35
College Station-Bryan, TX	0	1	0	0	1.01	0.85
Elkhart-Goshen, IN	0	0	0	0	0.81	0.58
Johnson City, TN	0	0	0	0	1.42	1.26
Medford, OR	1	0	108	168	0.81	0.71
Greeley, CO	0	1	28	48	0.66	0.55
Lafayette, IN	1	2	0	0	1.27	0.96
Kingston, NY	0	0	0	0	1.28	1.15
Bloomington, IN	1	1	8	28	1.06	1.05
Tyler, TX	0	1	0	0	1.01	0.79
Las Cruces, NM	0	0	0	0	2.86	4.76
Fargo, ND-MN	1	0	0	0	1.05	0.93
Charlottesville, VA	1	1	21	31	0.98	0.93
Terre Haute, IN	0	0	0	0	1.05	1.28
Fort Walton Beach-Crestview-Destin, FL	0	1	0	0	1.49	1.09
Muskegon-Norton Shores, MI	0	0	0	0	0.88	0.58
Monroe, LA	1	1	0	0	1.48	1.04
Prescott, AZ	0	0	0	0	0.74	0.80
St. Cloud, MN	1	1	150	210	1.07	1.05
Bellingham, WA	1	0	72	152	0.64	0.71
Athens-Clarke County, GA	1	1	0	0	1.20	1.32
Parkersburg-Marietta-Vienna, WV-OH	1	0	0	0	1.21	0.86
Waterloo-Cedar Falls, IA	0	0	0	0	1.02	0.91
Rochester, MN	1	0	21	31	1.24	1.48
Redding, CA	1	1	0	0	0.96	0.73
Niles-Benton Harbor, MI	0	0	0	0	1.14	0.60
Abilene, TX	0	0	0	0	0.70	0.59
Yuma, AZ	0	0	17	27	1.51	1.48
Jackson, MI	0	0	0	0	0.74	0.80
Albany, GA	0	0	0	0	1.53	1.50
Joplin, MO	0	0	19	29	1.04	1.09
Oshkosh-Neenah, WI	0	0	57	87	0.77	0.81
Lake Havasu City-Kingman, AZ	0	0	0	0	1.17	0.74
Wheeling, WV-OH	0	0	0	0	0.83	0.67
Greenville, NC	1	1	0	0	1.84	1.22
Johnstown, PA	0	0	0	0	0.83	0.90
Janesville, WI	0	0	19	29	1.17	0.86
Wichita Falls, TX	0	0	0	0	1.37	0.89
Blacksburg-Christiansburg-Radford, VA	0	0	0	0	1.02	0.48
Bloomington-Normal, IL	1	0	0	0	0.96	0.67
Jacksonville, NC	0	1	0	0	1.38	1.44
Eau Claire, WI	1	1	19	29	0.86	0.96
Panama City-Lynn Haven, FL	0	0	0	0	0.87	0.77
Vineland-Millville-Bridgeton, NJ	0	0	0	0	0.40	0.30
Monroe, MI	0	0	0	0	1.70	0.71
Decatur, AL	0	0	0	0	1.30	1.64
Columbia, MO	1	1	0	0	0.94	0.96

MSA	EMCE00	EMCE10	UCI00	UCI10	USI00	USI10
Alexandria, LA	0	0	0	0	0.87	0.83
Bangor, ME	1	1	0	0	1.18	0.94
Springfield, OH	0	0	0	0	0.85	0.68
Sioux City, IA-NE-SD	0	0	21	31	0.79	0.68
Rocky Mount, NC	1	1	0	0	2.04	1.72
El Centro, CA	0	0	0	0	2.00	1.72
Punta Gorda, FL	0	0	84	154	1.13	0.58
Pueblo, CO	0	0	0	0	0.60	1.87
Jefferson City, MO	0	1	0	0	1.42	1.59
Gainesville, GA	1	0	0	0	1.70	2.21
Yuba City, CA	0	0	30	60	1.25	1.08
Billings, MT	0	0	0	0	1.08	1.13
Battle Creek, MI	0	0	0	0	0.66	1.10
State College, PA	1	1	0	0	0.91	0.62
Pittsfield, MA	1	1	0	0	0.66	0.60
Weirton-Steubenville, WV-OH	0	0	0	0	1.09	0.68
Iowa City, IA	1	1	8	18	1.30	1.35
Dothan, AL	0	0	0	0	2.31	2.07
Burlington, NC	0	0	0	0	1.34	0.91
Texarkana, TX-Texarkana, AR	0	0	0	0	1.50	0.87
Hanford-Corcoran, CA	0	0	0	0	0.52	0.67
Santa Fe, NM	2	2	0	0	0.71	0.99
Altoona, PA	1	0	0	0	1.11	0.98
Mansfield, OH	0	0	0	0	1.14	0.76
La Crosse, WI-MN	0	0	57	87	1.32	1.13
Dover, DE	1	1	5	15	1.05	0.71
Wausau, WI	0	0	19	29	1.14	1.19
Glens Falls, NY	0	0	0	0	0.73	0.81
Napa, CA	0	0	0	0	0.45	0.46
Hattiesburg, MS	0	0	0	0	0.92	1.16
Madera, CA	0	0	0	0	0.90	1.61
Morristown, TN	0	0	0	0	1.32	1.18
St. Joseph, MO-KS	0	0	0	0	1.49	1.17
Odessa, TX	0	0	0	0	0.64	0.64
Lebanon, PA	0	0	0	0	1.55	1.89
Williamsport, PA	0	0	0	0	1.18	0.89
Dalton, GA	0	1	0	0	1.37	1.22
Valdosta, GA	0	0	0	0	1.29	1.07
Muncie, IN	0	0	0	0	0.75	0.73
Flagstaff, AZ	0	0	54	84	0.54	0.56
Grand Junction, CO	1	0	0	0	0.75	0.58
Midland, TX	0	0	0	0	0.62	0.26
Bend, OR	0	0	152	232	1.15	0.75
Auburn-Opelika, AL	0	0	0	0	0.96	0.98
Lawton, OK	0	0	25	35	1.44	0.44
Decatur, IL	0	0	0	0	0.96	0.88
Farmington, NM	0	0	0	0	0.83	0.77
Goldsboro, NC	0	0	0	0	1.36	1.03
Rapid City, SD	0	0	0	0	0.72	1.01
Sheboygan, WI	0	0	19	29	0.82	0.53

MSA	EMCE00	EMCE10	UCI00	UCI10	USI00	USI10
Anniston-Oxford, AL	0	0	0	0	1.41	0.89
Victoria, TX	0	0	0	0	1.38	0.73
Morgantown, WV	1	1	0	0	1.33	1.15
Warner Robins, GA	0	0	0	0	0.91	0.94
Sherman-Denison, TX	0	0	0	0	1.13	0.89
Bay City, MI	0	0	0	0	0.81	0.52
Michigan City-La Porte, IN	1	1	0	0	0.81	0.44
Owensboro, KY	1	1	0	0	1.38	1.39
Salisbury, MD	0	0	0	0	0.99	0.96
Coeur d'Alene, ID	0	0	0	0	0.95	0.78
Lima, OH	0	0	0	0	1.15	0.82
Harrisonburg, VA	0	1	0	0	1.06	0.94
Jonesboro, AR	0	0	0	0	1.78	1.16
Elizabethtown, KY	0	0	0	0	1.31	0.70
Jackson, TN	0	0	0	0	0.89	0.98
Pine Bluff, AR	0	0	0	0	1.19	1.64
San Angelo, TX	0	0	0	0	0.87	0.49
Sumter, SC	0	0	0	0	0.97	0.79
Bowling Green, KY	0	1	0	0	0.91	0.85
Cleveland, TN	0	0	0	0	1.22	1.01
Kankakee-Bradley, IL	0	0	0	0	0.93	0.69
Lewiston-Auburn, ME	0	0	0	0	1.20	1.01
Gadsden, AL	0	0	0	0	1.27	1.05
Winchester, VA-WV	0	0	0	0	1.73	1.48
Mount Vernon-Anacortes, WA	0	0	0	0	0.96	0.69
Logan, UT-ID	0	0	0	0	0.58	0.61
Ocean City, NJ	0	0	0	0	1.37	0.59
Cumberland, MD-WV	1	1	0	0	1.37	1.19
Idaho Falls, ID	0	1	0	0	1.56	1.49
Kokomo, IN	1	0	0	0	1.01	1.02
Lawrence, KS	0	0	0	0	1.08	0.80
Wenatchee, WA	0	0	0	0	1.53	0.55
Grand Forks, ND-MN	0	0	0	0	1.02	0.83
Fond du Lac, WI	0	0	19	29	1.17	1.12
Ithaca, NY	0	0	0	0	0.93	0.90
Missoula, MT	0	0	0	0	0.62	0.85
Bismarck, ND	1	1	38	58	0.72	0.69
Brunswick, GA	0	0	0	0	1.68	0.84
Longview, WA	1	0	0	0	0.77	0.75
Elmira, NY	0	0	0	0	0.53	0.43
Rome, GA	0	0	0	0	0.94	0.86
St. George, UT	0	0	0	0	0.89	0.77
Dubuque, IA	0	0	0	0	0.81	0.78
Hot Springs, AR	0	0	0	0	1.01	0.93
Danville, IL	0	0	0	0	1.02	0.77
Pocatello, ID	0	0	0	0	0.73	0.65
Cheyenne, WY	0	0	0	0	0.51	0.35
Great Falls, MT	0	0	0	0	0.41	0.43
Ames, IA	0	0	0	0	0.80	0.57
Corvallis, OR	0	0	128	208	0.70	0.54

MSA	EMCE00	EMCE10	UCI00	UCI10	USI00	USI10
Hinesville-Fort Stewart, GA	0	0	0	0	1.23	0.91
Columbus, IN	0	0	0	0	1.28	1.44
Casper, WY	0	0	0	0	0.46	0.31
Lewiston, ID-WA	0	0	0	0	1.19	0.66
Carson City, NV	0	0	0	0	0.42	0.11